Control ENGINEERING

INSTRUMENTATION AND CONTROL SYSTEMS

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APRIL 1960

Goodrich Eases into Computing-Control

Controlling Continuous-Flow Reactors

Valve Supplier Solves European Market

Updating Process Instrument Costs

Welding Control Uses New Components

Evaluating Today's Proximity Switches

Controls Automatically True Bike Wheels

Transistor Length Gage Scans Hot Steel

Holland Mechanizes Air Traffic Control

Novel Caging Scheme for Inertial Platforms

Logging Time Charges on Five Computers

Differential Pressure Measuring Circuits

Developing Movie Film in 60 Seconds

Techniques of Dynamic Display

Computer Circuits for Root Locus

Statistical Computers Really Reduce Data

Russian Train Computer Controlled

Hybrids for Close-Differential Switching

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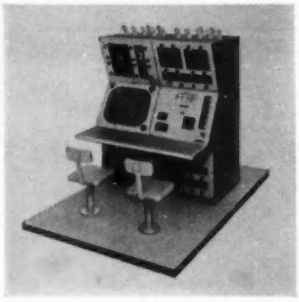

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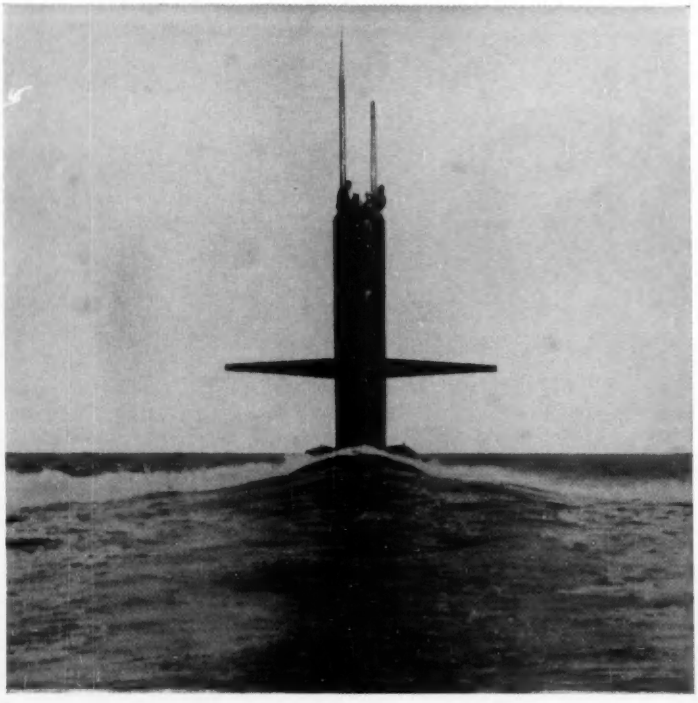

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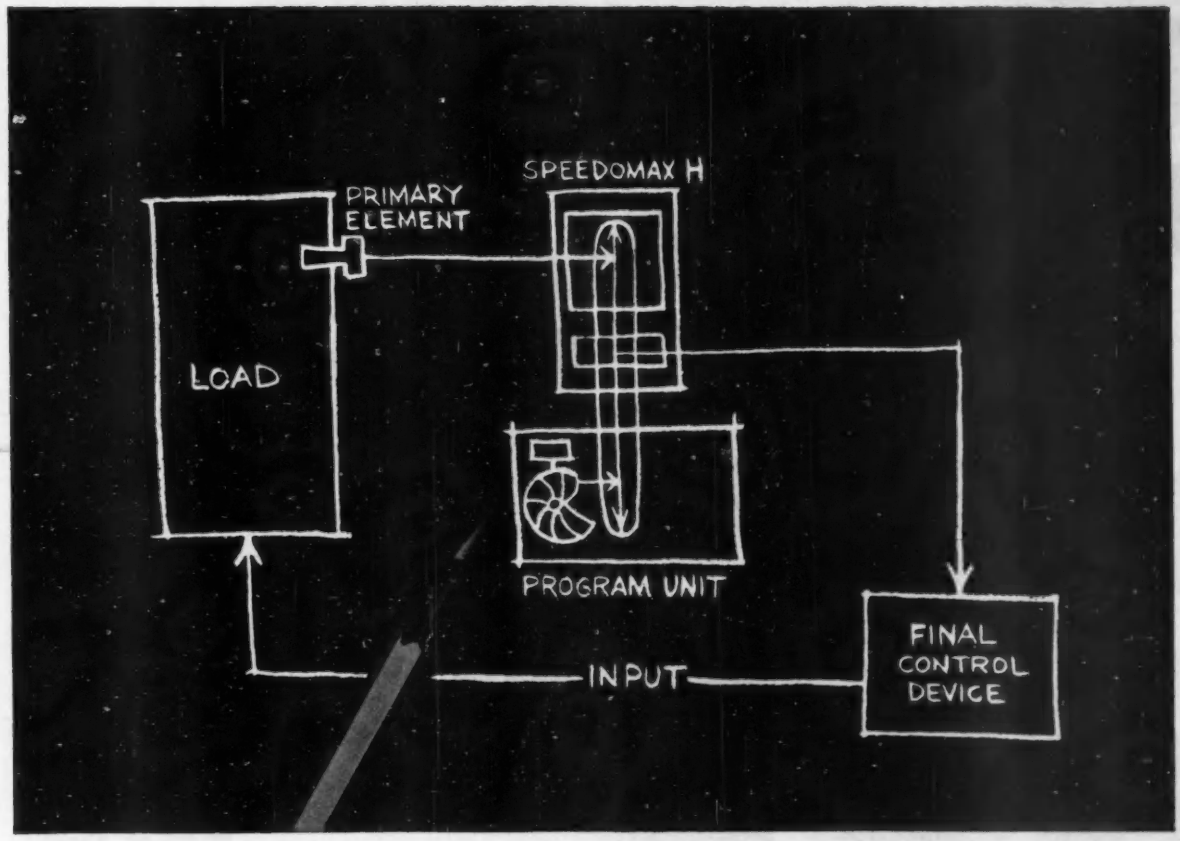

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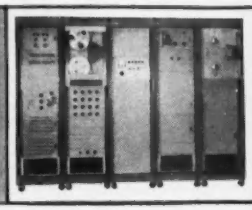

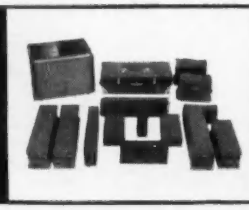

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Control ENGINEERING

APRIL 1960
VOL. 7 NO. 4

Published for engineers and technical management men who are responsible for the design, application, and test of instrumentation and automatic control systems

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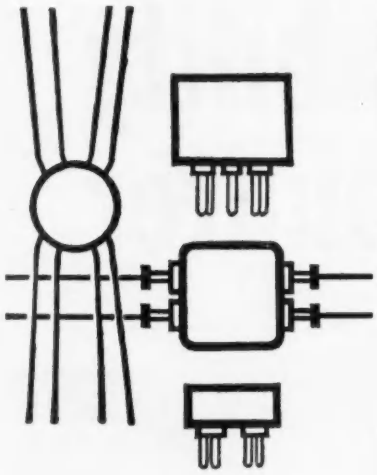

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Three dozen data files

This issue contains the thirty-sixth Data File published in CONTROL ENGINEERING. A popular feature since its start in January 1957, this continuing series of short-cut analysis, design, and application techniques has encompassed all the nooks and crannies of the control field. Reader demand for reprints of these articles prompted us to republish them in 12-article packages, the third of which becomes available with this issue. Individual copies of these reprints—Ready Reference Data Files—I, II, and III—are available at 50 cents, 50 cents, and 60 cents, respectively. But for those readers who want all 36 Data Files we've come up with a special combination price of $1.35. See Reprint Department on page 215 for the details.

First user reveals details

Hats off to B .F. Goodrich Chemical Co. for being the first user to contribute much of its know-how and experience stemming from the successful computer control of a chemical process. BFG's computer expert and spokesman James M. Madigan made general disclosures about the project at an AIChE meeting in Chicago and an AMA symposium in New York. To develop a more detailed picture for CtE readers, Madigan agreed to answer all questions put to him by CtE's Associate Editor Harry Karp on the system's instrumentation, computer functions, project teamwork, installation problems, and cost. For Jim's story as related to Harry see page 20.

Control, computers, digits, and statistics

Since 1933 Ernest J. Schubert has been designing computers and control systems, starting his career as a logical designer for electromechanical accounting machines. During the ensuing 27 years Schubert was in charge of development of automatic telephone exchanges, interlocking and remote control for large European railroad systems, and early digital servos for process control, meanwhile obtaining his D.Sc. in applied physics from the University of Vienna. For seven years he was president of an Austrian corporation manufacturing relay servos and digital controls for chemical and pharmaceutical industries. After crossing the ocean, Dr. Schubert taught, consulted, developed advanced magnetic computers, and supervised systems research in Canada and the U. S. His current activity in statistical control techniques (see "Statistical Computers can Really Reduce Data", page 146) keeps things interesting in his position as technical director of Monitor Systems, Inc., a subsidiary of Epsco, Inc.

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Tandem unit. Transmitter and Resolver.

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Accuracy: ±4′ max. error.

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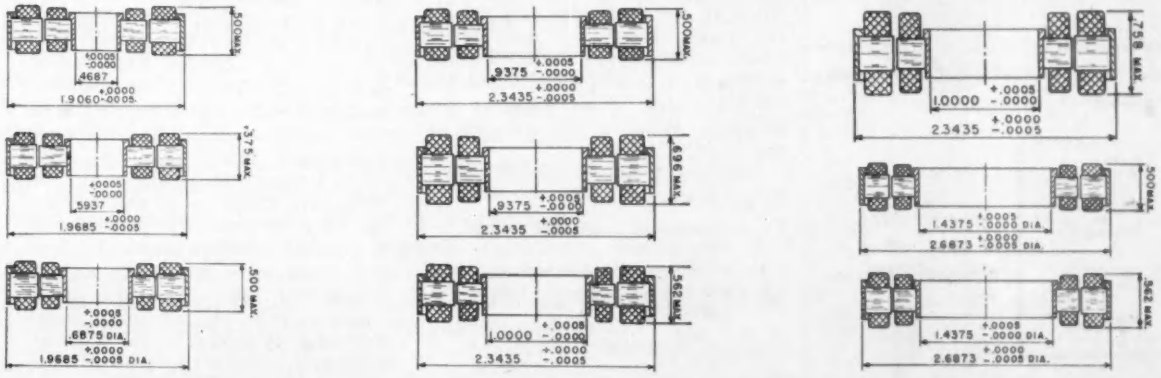

ENGINEERS—Pioneer with a leader in the field. Write David D. Brown, Director of Personnel, Dept. A3.

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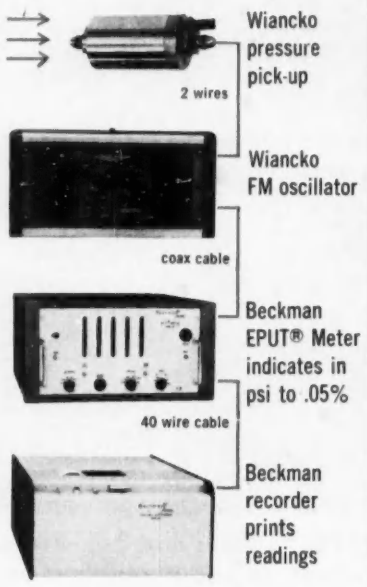
MEASURING PRESSURE?

Now you can assemble complete digital systems using only off-the-shelf components. All equipment is matched output-to-input to save engineering time and the cost of specially-tailored hardware. The simple system below may be expanded ten-fold in complexity.

ASSEMBLED BUILDING BLOCKS MAKE A DIGITAL SYSTEM...



Building blocks for measuring temperature, force, flow and rpm are equally available.

Write for free 16-page survey of illustrative systems

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25 YEARS

J 31

FEEDBACK

What kind of engineer are you?

TO THE EDITOR—

By the question we do not mean—are you electrical, mechanical, chemical, metallurgical, or other. We mean are you a plodder or an imaginative original thinker?

Now the plodders and work-horses have their place; they do a technician's work of low and high degree. They can apply textbook formulas and solve problems to build bridges and make wheels go around. However they sometimes make an involved problem out of a situation which lends itself to an almost immediate answer, if the approach is an imaginative one backed up by broad concepts such as energy flow and relative velocities—or if the approach is oblique. Academic teaching is largely confined to "Can you solve this problem?"—rather than "How many different ways can you solve this one, and which do you consider best?"

In practical engineering work it is generally possible to hire an engineer who can manage to get a given job done. The high-priced engineer who is hard to find is the one who can visualize the "dozen ways to skin a cat", exercise sound judgement as to which channel the firm's (or government's) money could best be applied to, and direct someone to work out the details.

We posed a simple problem to three engineers. "A man is rowing a boat upstream in a river. He drops his hat in the water but doesn't notice. He keeps on rowing 10 minutes. Then he notices he has dropped his hat, turns around, and rows downstream with the same effort he was putting forth rowing up. He catches his hat a mile below where it was dropped. What is the velocity of the river?"

Engineer A took pencil and paper. He set down

V_B = velocity of boat with respect to river, mi/min
V_R = velocity of river with respect to land
X = distance above starting point reached in 10 min

then $\frac{X}{V_B - V_R} = 10$

until he found $V_R = 3$ mi/hr.

Engineer B said that from the statement of the problem the answer must be the same regardless of the velocity of the boat with respect to the river. So to make things easy we can assume $V_R = V_B$. Then the boat stands still when the man rows upstream. Likewise when he turns around the boat is moving at twice the velocity of the water. Thus, it is obvious the hat goes a mile in 20 minutes.

Engineer C, however, had the clear perspective. Boat and hat were in the some continuum—water. What difference did it make where the land was going? The man rowed in a straight line away from the hat for 10 minutes—ergo he had to row 10 minutes to get back to it.

Since the moral was stated before the illustration, this about ends the story. Engineer C is the man to hire—he reaches the answer quickest, thus saving payroll dollars. You may be sure that if he must use equations, his formulas will be the most simple and direct, with minimum possibility of errors which may cause further direct and indirect loss.

A little postscript moral is that we hear much of scarcity of engineers, and a certain country may be growing more engineers than we are per acre. Perhaps the quantity we have is adequate, if more could be the caliber of C. It is questionable whether the quantity of real creative talent can be increased by artificially attracting more half-hearted youngsters into the ranks.

Charles T. Button
Wright Manufacturing Co.
Durham, N. C.

Trib muddles CtE story.

TO THE EDITOR—

There is attached a copy of an article from the New York *Herald Tribune* crediting CONTROL ENGINEERING as the source. You will note that one paragraph states that France's domestic control industry is $62 million a year. The next paragraph states ". . . United States-made control instruments, which up to now account for about 38 percent of the $24 million industry in that country. . . ."

I assume by this it is actually meant that "the United States-made control instruments up to now account for about 38 percent of the $62 million dollar industry in that country, which is about $24 million."

$62 million worth of automatic control instruments is quite a tidy sum and would keep an automatic control manufacturing plant quite busy. I assume you can clarify the statement

Replace Complete Trim Without Removing Valve From Line!

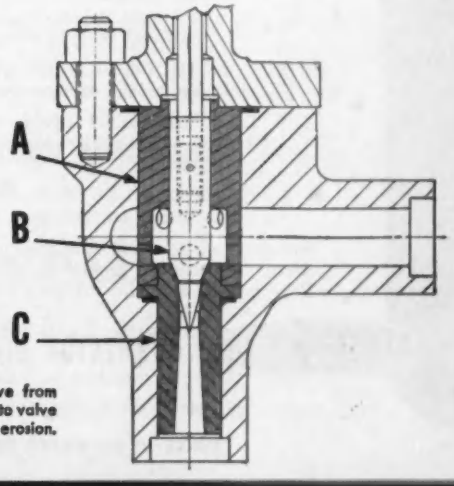
Rockwell-built Republic V-10 valves with Quick-change Trim save many hours of downtime on severe energy conversion applications with pressure drops up to 3500 lbs.

The Republic V-10 angle valve for high-pressure liquid or steam regulating services offers unique valve maintenance advantages because of its Quick-change Trim construction.

Quick-change Trim in the V-10 valve makes it possible for you to replace the valve seat, inner valve and guide in little more time than is required to dismantle and reassemble a bolted joint. No time is required for lapping the seating surfaces of the valve, since this is done in advance. *And you can make this quick trim change in minutes without removing valve from the line.* The savings to you are considerable in downtime and maintenance expense.

Republic V-10 Valves are available with either welded seat or replaceable seat, in addition to the Quick-change Trim design, with bolted or pressure seal bonnets. V-10 valve contours are designed to produce not only the desired regulating characteristics, but also to reduce erosion damage and noise as well. Precise manufacture and long-life materials make Republic regulating valves perform better, last longer, with less maintenance. For additional information, contact your nearest Republic Representative, or write to Republic Flow Meters Company, 2240 Diversey Parkway, Chicago 47, Illinois. In Canada: Republic Flow Meters Canada, Ltd., Toronto. Subsidiary of Rockwell Manufacturing Company.

Rockwell-Republic V-10 regulating valve with Type J-1 positioner is designed for rugged high-pressure liquid or steam service.



Quick-change Trim feature makes it possible to replace the seat guide (A), inner valve (B), and seat (C), without removing valve from the line. Seat extends to valve outlet to prevent body erosion.

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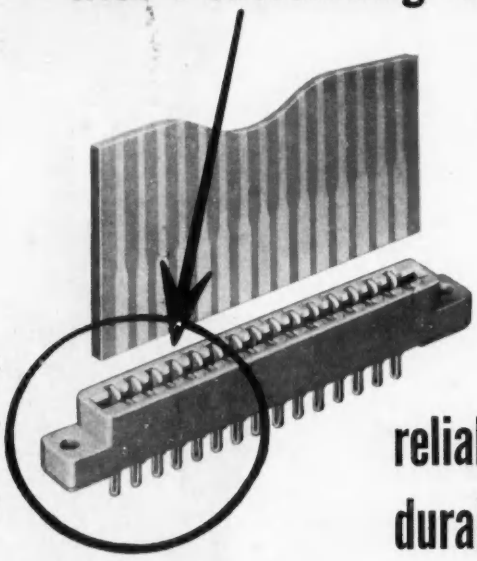
unique contact

with 4 outstanding features



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3. LOW MILLIVOLT DROP—After 1000 insertions and withdrawals in reliability-durability testing the millivolt drop is negligible. Only after 5000 cycles is it appreciably affected.
4. HARD GOLD-OVER-ALBALOY PLATING—Assures low electrical contact resistance, prevents tarnishing.

Princir receptacles are available with from six to twenty two contacts; there are five contact tail types. A complete family of mating Princir plugs and adapters are also available.

AMPHENOL CONNECTOR DIVISION
CHICAGO 50, ILLINOIS
Amphenol-Borg Electronics Corporation

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FEEDBACK

and determine for me how broad a term you are assigning to the word "control" instruments.

Paul C. Sharp
Minneapolis-Honeywell Regulator Co.
Minneapolis, Minn.

The *Herald Tribune's* pick up of this item from our original story left out one very important word. Our article said that U. S. makers' share was 38 percent of France's $24 million a year instrument and control *imports*. It also said that U. S. licensing is responsible for much of France's domestic $62 million/year control industry.

The instruments and controls that make up this $62 million a year industry include scientific instruments, process instruments, process control, machine tool and machinery control, computers, etc. Ed.

We, not the Russians did it first.

TO THE EDITOR—

Late last winter or early spring [May, '59, p. 31, Ed.] you published an article about Russia developing [we used the word "push", Ed.] a method of controlling a blast furnace. This has been covered for some time by a U. S. Patent held by Otto Leone. In fact U. S. Steel was in the process of installing this method and is probably using it by now.

Millard S. Gaut
Albany, N. Y.

Can do if detect skew

TO THE EDITOR—

Letters on sheet length measurement in the August '59 issue (page 10) were expecially interesting to us because we have just finished a two-year development of equipment to measure sheet length to 0.001 in. One factor that was particularly difficult to overcome presented itself early in the game. It was that even the smallest errors in presentation of the sheet, although unimportant where wide tolerances are permitted, are inadmissible when measurement is made to 0.001 in. This made it necessary for us to work out techniques whereby the electronic circuitry would be infallible despite skewing of the sheet.

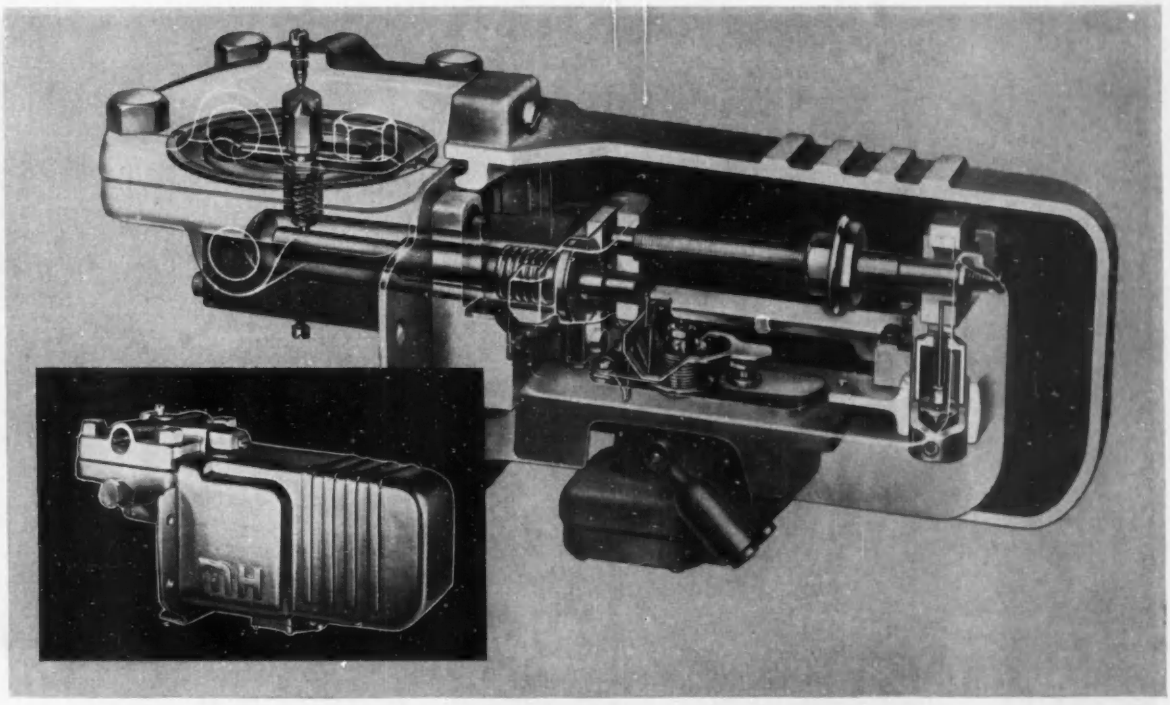
Sterns Control Corp.
Great Neck, N. Y.

The circuit mentioned employs multiple photocells to detect skew and logical timing circuits to measure and compensate for skew. The circuit and the entire measuring system will be described in CtE. Ed.

ROCKWELL

CIRCLE 9 ON READER SERVICE CARD

the line. Seat extends to valve outlet to prevent body erosion.



Three Honeywell Differential Converter* models give you...

Full-range control of flow and liquid level

1. For measuring gas and water flows: One model has a range of 0-5 to 0-25 inches of water. It can also be adapted to the measurement of specific gravity of liquids in open tanks. Available with *Buna-N* diaphragm.

2. For measuring liquid level in closed tanks: One model has a range of 14 to 50 inches of water, with maximum suppression of 75 inches. Another model, with a range of 50 to 200 inches of water, has maximum suppression of 200 inches. Available with *Teflon*** or *Viton A*** diaphragm.

3. For measuring flow and liquid level in open tanks: Two models with ranges from 0-20 to 0-200 inches of water differential and 0-100 to 0-1000 inches. Available with *Teflon* or *Viton A* diaphragm.

Now, standard models of the *Differential Converter* cover any range from 0-5 to 0-1000 inches of water—the widest choice of ranges we know of. And newly available *Viton A* and *Teflon* diaphragms make the *Differential Converter* ideal for a wide variety of applications. *Teflon* diaphragms are well suited for use with hard-to-handle fluids. *Viton A* has excellent mechanical properties which practically eliminate zero drift.

The *Differential Converter* measures gas and liquid flow or liquid level with accuracy within ±1% . . . and with rapid response, upscale and down. Range is continually adjustable in the field, without parts change, and field calibration is easily checked without weights. Air consumption is extremely low.

Compact and lightweight, these mercuryless transmitters can be mounted anywhere. They're ideal companions for Honeywell *Tel-O-Set** miniature instruments. Call your nearby Honeywell field engineer for full details. He's as near as your phone.

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*Tradename, Minneapolis-Honeywell

**Tradename, E. I. du Pont de Nemours & Co., Inc.

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Honeywell

First in Control

SINCE 1885

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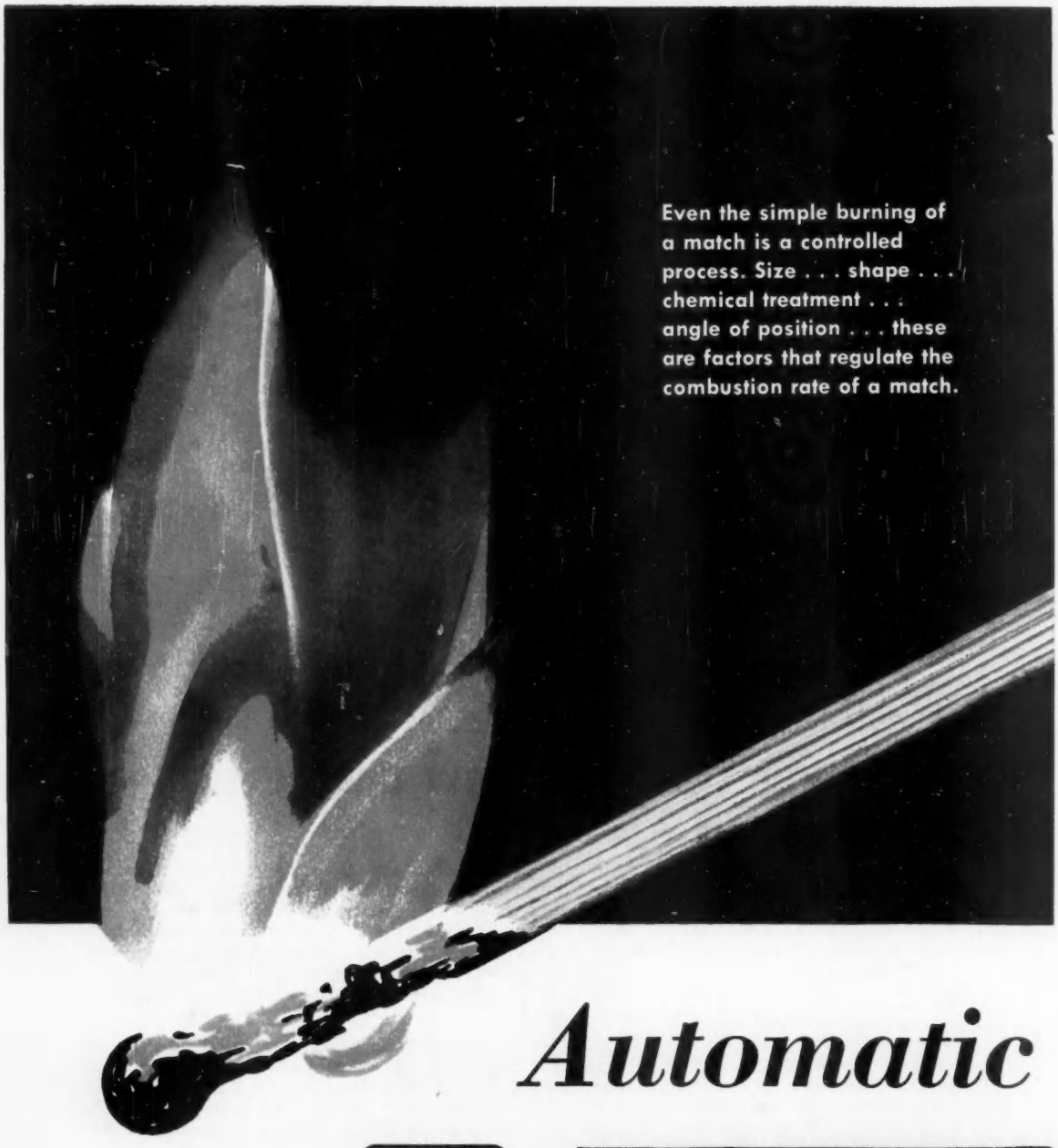
CIRCLE 10 ON READER SERVICE CARD


Even the simple burning of a match is a controlled process. Size . . . shape . . . chemical treatment . . . angle of position . . . these are factors that regulate the combustion rate of a match.

Automatic

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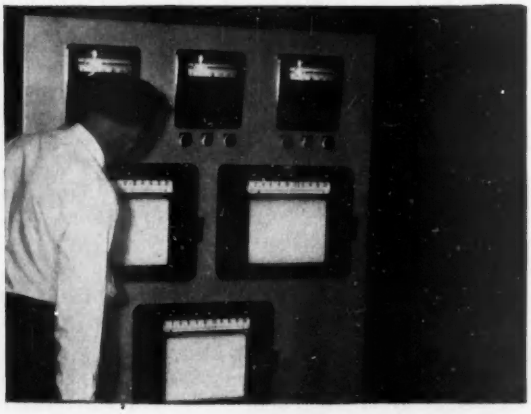

Process Control...

Just as the controls for a match are tailored to meet specific requirements, Wheelco systems are tailored to meet your requirements for automatic process control, combustion safeguards and gas chromatography. Experienced engineering, modern production facilities and instrument reliability backed by a world-wide service network are your reasons for specifying Wheelco systems. Tell us about your process control problems. Contact your nearby Wheelco sales office.

At Left: The Wheelco control center in a large Midwestern heat-treating plant uses Limitrols and 8000 Series Recorders for operating a continuous three-zone electric furnace with capacity of 1000 lbs. per hour.

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BARBER-COLMAN COMPANY

ALLIED'S New CRYSTAL CAN 5 amp Relay

GENERAL FEATURES

Contact Arrangement:
Two pole double throw.

Contact Rating:
d-c non-inductive—low-level
up to 5 amperes at 29 volts.

a-c non-inductive—low-level
up to 2 amperes at 115 volts.

a-c or d-c inductive—1 ampere
at 29 volts d-c and 115 volts a-c.

Initial Contact Resistance:
.05 ohms maximum.

Minimum Operate Sensitivity
100 milliwatts with a contact
rating of 2 amperes non-inductive.

Ambient Temperature:
−65°C to +125°C.

Dielectric Strength:
1,000 volts rms at sea level.
450 volts rms at 70,000 feet.
350 volts rms at 80,000 feet.

Insulating Resistance:
10,000 megohms minimum.

Vibration:
5-28 cps at 0.5 inch double
amplitude and 28-2000 cps at 20 g.

Shock: 50 g operational. 100 g mechanical.

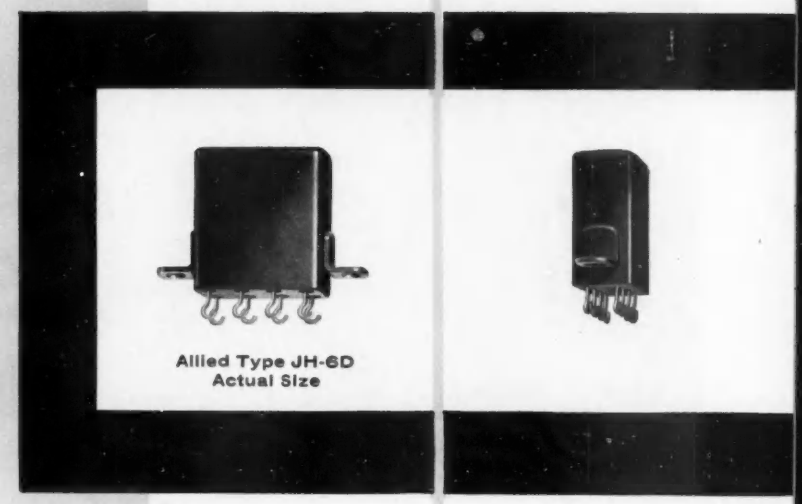
Operate Time:
10 milliseconds or less at rated voltage at 25°C.

Release Time:
5 milliseconds or less at rated voltage at 25°C.

Maximum Over-all Dimensions:
height 1.0" length 0.8" width 0.4".

Terminals:
0.2 inch grid spaced. Plug-in printed circuit
and hooked type solder terminals.

Weight: 0.8 ounces maximum.



Allied Type JH-6D
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ALLIED CONTROL

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CIRCLE 14 ON READER SERVICE CARD

A CONTROL PERSONALITY

Howard H. Rosenbrock
tackled the windmills

At first glance, control engineer Howard Rosenbrock has little in common with Don Quixote, Cervante's swashbuckling hero who tilted with windmills. Rosenbrock's battle against process control unknowns with purely mathematical lances evokes only some faint reminisces. But it is the windmill that makes the similarity really convincing.

A windmill that was never built started Rosenbrock in the control field. In 1948 he joined the staff of the Electrical Research Association, an all-industry body concerned with conserving Britain's meager fuel resources. He was assigned to plan the instrumentation for a prototype windmill generating station—a chain of such stations was planned to supply 2,000 megawatts of power for England's west coast.

Developing a fast response windspeed and gust recorder, Rosenbrock startled blade designers and meteorologists by isolating tremendous changes in windspeed, as much as fifty miles per hour in two sec. This so complicated the design that Rosenbrock found himself suddenly drafted into that aspect of the project. Before he knew it, he was sorting blade flutter for 30-ft windmill arms on the windswept Orknev Islands, site of the first windmill to be built by John Brown Ltd.

To solve this flutter problem, Rosenbrock evolved a mathematical approach that earned him a Ph.D degree from London University and so impressed the John Brown company that he was invited to join Brown's research team. His first job was back at the windmill: designing a speed governor system and completing a frequency response analysis of it.

At this point, enthusiasm for Britain's burgeoning nuclear power program quietly folded the windmill project. Howard Rosenbrock transferred to John Brown's associate, Costain John Brown Ltd (chemical plant erectors who have since become Constructors John Brown Ltd.), as a mathematician, because he had become intrigued by the similarity between control system mathematics and those that won his doctorate.

In his new position he was able to devote full time applying mathematical analysis to process control. He prepared a series of papers, which he presented at the London Institution of Electrical Engineers, describing error-squared servos, graphical methods of frequency analysis, and interconversion of transient and frequency response (the latter described in CtE, July '59, p. 116). His approach to interconversion was so well received that sales of his cursors are still going strong.

When the company expanded from straight chemical plant construction into process design, Rosenbrock became head of a new research and development section. His first project: an analysis of distillation columns. It took five years to come up with a solution because, as he puts it, "I was naive at the time; I thought the operation was understood and the equations known."

Although he did find the transfer functions of columns already installed, Rosenbrock holds little hope for the possibility of developing routine methods in the near future for predicting distillation column performance before it is built.

What can be done now is a step-by-step analysis to determine tower equilibrium conditions. When equilibrium is set up, disturbances are introduced to determine what happens to composition as a new equilibrium position is reached. By examining each plate the control engineer can choose the most appropriate measuring points for the control system. Finally, a simulation of the transfer function and the proposed control system on an analog computer yields a good forecast of expected overall system performance.

Rosenbrock will detail this method in a technical paper at the International Federation of Automatic Control Congress in Moscow in June. Meanwhile, he has already started on his next research project: chemical reactor analysis.

All this is a long way from his start at London University where he majored in communications and electrical engineering. Rosenbrock was one of the English engineers whose professional development was suspended by the war. After six years in the India-Burma theater, as a ground crew member of the Royal Air Force, he returned to England as a research engineer at General Electric Co., working on radio transmitters. He also was a teacher before he met his first windmill.

ALLIED CONTROL COMPANY, INC., 2 EAST END AVENUE, NEW YORK 21, N.Y.
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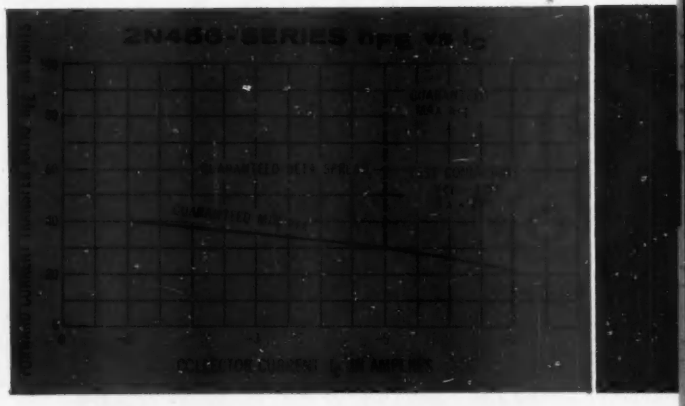
FULL LINE OF HIGHEST BETA GER

New TI high-efficiency emitter gives you high beta germanium power transistors!

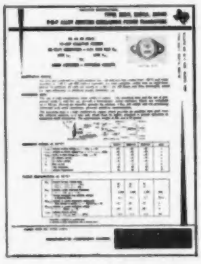
Now minimum and maximum betas are guaranteed from 20 to 60 at the maximum current rating of I_C = 25 amps in new TI 2N514 series transistors. New high efficiency emitter makes possible greatly improved specifications for TI 2N456, 2N511, 2N512, 2N513, 2N514, and 2N1021 series alloy-junction germanium power transistors.



TI gives you design leadership in quality germanium power transistors

INCREASED BETA THROUGH HIGH-EFFICIENCY EMITTER

Emitter efficiency can be improved by increasing the ratio of resistivities between the emitter and base region. For example, when a 10 ohm-centimeter resistivity germanium wafer is used as the base material, it is advantageous to have less than a .01 ohm-centimeter resistivity emitter regrowth region. Since initial doping of the germanium crystal establishes base resistivity, the ratio can be changed only by varying the emitter material. TI utilizes an emitter material that results in a lower emitter resistivity and an increased emitter efficiency, plus providing the higher beta at high currents.



Optimum reliability for all TI germanium power transistors is assured by . . . 100% testing . . . 100% temperature cycling . . . 100% hermetic seal testing . . . continuous and intensive quality assurance program. Write on your company letterhead for germanium power transistor specifications.

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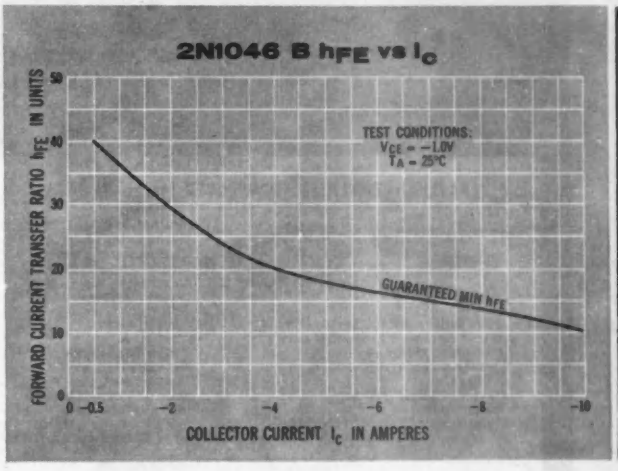
MANIUM POWER TRANSISTORS

New high current 2N1046-A-B give you high frequency/dissipation/voltage with high beta!

New TI 2N1046B germanium power transistors give you 10 amp I_C with typical 18 mc f_T* . . . 130 volt BV_{CBO} . . . guaranteed beta of 10 at 10 amp I_C . . . 30 watt dissipation . . . high frequency/high current operating characteristics. The 2N1046 series alloy-diffused P-N-P transistors provides maximum reliability for your core driving, hi-fi amplification, and other high frequency power applications.

f_T* *Frequency at which common base current gain of the device is unity.*



Call on your nearest TI distributor or sales office for immediate delivery of TI germanium power transistors including the 1-amp 2N1038 series and the 3-amp 2N1042 series power transistors.

TI GERMANIUM POWER TRANSISTOR CHARACTERISTICS AT 25°C

Type	Dissipation at 25°C watts	Collector to Base Voltage-v max	Collector to Emitter Voltage min BV_{CEO}	Emitter to Base Voltage-v min BV_{EBO}	Collector Current Amps max	h_{FE} @ I_C min	h_{FE} @ I_C max	Collector Reverse Current I_{CO} max ma	Collector Reverse Current I_{CO} max v	Typ R_{CS} @ I_C ohms	Internal Cutoff Frequency avg f_T
2N456A	50	−40	−20	−20	−7	30 @ 5a	90	−0.5	−20	0.040 @ 5a	430 kc
2N457A	50	−60	−30	−20	−7	30 @ 5a	90	−0.5	−30	0.040 @ 5a	430 kc
2N458A	50	−80	−40	−20	−7	30 @ 5a	90	−0.5	−40	0.040 @ 5a	430 kc
2N1021	50	−100	−50	−20	−7	30 @ 5a	90	−0.5	−50	0.040 @ 5a	430 kc
2N1022	50	−120	−50	−20	−7	30 @ 5a	90	−0.5	−60	0.040 @ 5a	430 kc
2N511	80	−40	−20	−30	−25	20 @ 10a	60	−2	−20	0.025 @ 10a	260 kc
2N511A	80	−60	−30	−30	−25	20 @ 10a	60	−2	−30	0.025 @ 10a	260 kc
2N511B	80	−80	−40	−30	−25	20 @ 10a	60	−2	−40	0.025 @ 10a	260 kc
2N512	80	−40	−20	−30	−25	20 @ 15a	60	−2	−20	0.033 @ 15a	280 kc
2N512A	80	−60	−30	−30	−25	20 @ 15a	60	−2	−30	0.033 @ 15a	280 kc
2N512B	80	−80	−40	−30	−25	20 @ 15a	60	−2	−40	0.033 @ 15a	280 kc
2N513	80	−40	−20	−30	−25	20 @ 20a	60	−2	−20	0.038 @ 20a	300 kc
2N513A	80	−60	−30	−30	−25	20 @ 20a	60	−2	−30	0.038 @ 20a	300 kc
2N513B	80	−80	−40	−30	−25	20 @ 20a	60	−2	−40	0.038 @ 20a	300 kc
2N514	80	−40	−20	−30	−25	20 @ 25a	60	−2	−20	0.040 @ 25a	350 kc
2N514A	80	−60	−30	−30	−25	20 @ 25a	60	−2	−30	0.040 @ 25a	350 kc
2N514B	80	−80	−40	−30	−25	20 @ 25a	60	−2	−40	0.040 @ 25a	350 kc
2N1038	20	−40	−30	−20	−3	20 @ 1a	60	−125μa	−20	0.150 @ 1a	8.0 kc $f_{\alpha e}$ min
2N1039	20	−60	−40	−20	−3	20 @ 1a	60	−125μa	−30	0.150 @ 1a	8.0 kc $f_{\alpha e}$ min
2N1040	20	−80	−50	−20	−3	20 @ 1a	60	−125μa	−40	0.150 @ 1a	8.0 kc $f_{\alpha e}$ min
2N1041	20	−100	−60	−20	−3	20 @ 1a	60	−125μa	−50	0.150 @ 1a	8.0 kc $f_{\alpha e}$ min
2N1042	20	−40	−30	−20	−3	20 @ 3a	60	−125μa	−20	0.167 @ 3a	8.0 kc $f_{\alpha e}$ min
2N1043	20	−60	−40	−20	−3	20 @ 3a	60	−125μa	−30	0.167 @ 3a	8.0 kc $f_{\alpha e}$ min
2N1044	20	−80	−50	−20	−3	20 @ 3a	60	−125μa	−40	0.167 @ 3a	8.0 kc $f_{\alpha e}$ min
2N1045	20	−100	−60	−20	−3	20 @ 3a	60	−125μa	−50	0.167 @ 3a	8.0 kc $f_{\alpha e}$ min
2N1046	30	−100	−50	− 1.5	−10	40 @ 0.5a		−1	−40	0.500 @ 1a	15 mc min
2N1046A	30	−140	−50	− 1.5	−10	20 @ 4a		−1	−40	0.125 @ 4a	15 mc min
2N1046B	30	−140	−50	− 1.5	−10	10 @ 10a		−1	−40	0.050 @ 10a	15 mc min

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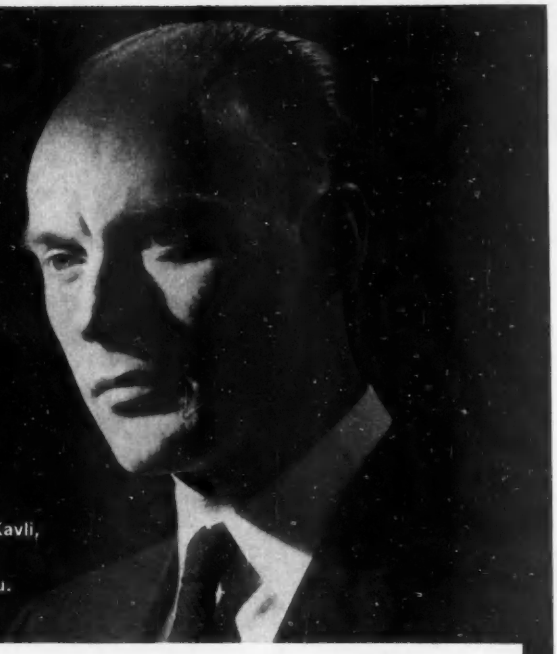


expect greater ACCURACY from KAVLICO TRANSDUCERS

The experience of Fred Kavli, who designed these transducers, is available to you.

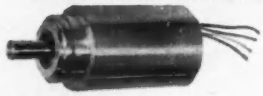
KAVLICO CONVERTER TRANSDUCER Model GM-9026

Input Voltage: 6V to 25V 400 CPS
Output Voltage: 0 to 5V DC (Polarity reversed at Null position)
Threshold Sensitivity: .0001% of full range
Linearity: Within 2% over ±¼"
Temperatures: −320°F to 250°F
Vibration: To 35 g's; to 2000 CPS

TYPICAL APPLICATIONS: telemetering of displacement; general laboratory purposes; as sensor in scales, material test machines, flow meters, machine control, etc.

OTHER CONVERTER TRANSDUCERS with features such as: 500V D.C. output per inch displacement; .05% Linearity; strokes up to 15"; various sizes and mechanical configurations.

KAVLICO ROTARY TRANSDUCER Model GM-9060



Linearity: ±½%
Output: 5V full scale
Input: 26V 400 CPS
Resolution: Infinite
Phase Shift: 5° max.
Rotary range: GM-9060A ±90°
GM-9060B ±180°
GM-9060C ±360°
Temperature range: −65°F to +300°F
Vibration: To 35 g's; to 2000 CPS

Used as feedback transducers for rotary actuators, valves, machine control, various aircraft and missile applications.

Other angular position transducers are available on special order with full scale displacements of ±40° to ±10 revolutions and temperature range from −65°F to 600°F.

KAVLICO VELOCITY TRANSDUCER Model VT-8-3.5

Housing length: 3.5"
Linear range: .7"
Output: .1 V/in/sec.
Diameter: .500"
Linearity: ±1%
***No excitation required.**

Other velocity transducers provide: 1 V output per inch, per second; stroke up to 15 feet.

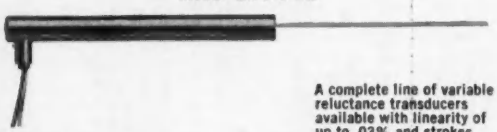
Provides: a D.C. ouput signal proportionate to velocity of linear motion of core; velocity feedback signal for servosystems; direct measurement of velocity of movement with increased accuracy and simplicity.

LINEAR DIFFERENTIAL TRANSFORMER Model GM-8013 TEMPERATURE COMPENSATED

Input: 26V 400 CPS
Stroke: ±.7"
Linearity: 1%
Output: 8 Volt/inch @ 26V 400 CPS input
Change in gain over temperature range: .005%/°F.
Temperature range: −65°F to +300°F
Vibration: To 35 g's; to 2000 CPS
Housing Length: 4"
Housing Diameter: ⅜"

Other models with shorter and longer stroke available. Most extensively used in actuators in missiles and aircraft to provide feedback signal for servosystems. Models have been designed and are available for 5Kc square wave excitation.

KAVLICO VARIABLE RELUCTANCE TRANSDUCER Model RA-3-6-1.5



Stroke: .5"
Linearity: .5%
Output: 1.2 V/in/V
Input: 10V 3000 CPS
Temperature: −65°F to +300°F
Housing Length: 1½"
Housing Diameter: ⅜"

A complete line of variable reluctance transducers available with linearity of up to .03% and strokes up to 8.5 inches. Some models will operate at 1000°F continuous duty and 1200°F intermittent duty. Used extensively for measurement.

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Your inquiry will receive an immediate reply from engineers experienced in the design and application of transducers for the solution of measurement and control problems.

Newsbreaks In Control

● Post Office Modernization Takes Training

Providence, R. I.—Post Office Dept. and International Telephone and Telegraph Co. have opened a unique school here to train postal employees in the use of automatic equipment which is to be installed at the $16 million modern Operation Turnkey post office (CtE, May '59, p. 22). Each clerk will receive 240 hours of training.

● Predictive Analysis, Key to Machine Translation

Cambridge, Mass.—In Harvard University's Computation Laboratory, scientists have developed a technique of "predictive analysis" which may speed the machine translation of Russian into English. The technique attempts to identify the grammatical role of each word in a sentence. Then each word determines the most probable grammatical form of the next word in the sentence. At end of sentence, machine checks to see that all the requirements for a complete sentence have been met.

● Spectrometer Dictates Truck Maintenance Schedule

Oakland, Calif.—A California trucking company has broken away from traditional truck maintenance schedules requiring a change of oil, piston rings, and valves after certain mileages. Instead, the company has set up a photospectrometer and analyzes crankcase oil on a regular basis. Based on the number and kinds of particles found in the oil, the company determines when to change oil and perform other engine maintenance.

● NASA Readies Orbiting Observatory Proposals

San Francisco—National Aeronautics and Space Administration is readying bid requests on an orbiting astronomical observatory to carry out ultraviolet radiation studies in a group of experiments that cannot be performed on the ground. Device will need special stabilization: orientation within 0.1 sec of arc. NASA hopes to get such stability from a combination of gas jets and an inertial system.

● What's Next in Computing-Control?

New York—Next step in the application of computers to production processes: the automatic control of production testing. One computer manufacturer selling this approach at the 1960 IRE show expects a major share of its business to be in this area. Typical approach: the testing of a magnetic amplifier in which many points have to be measured and a calibration curve calculated and then compared to a standard curve.

Goodrich Eases Into Computing Control

Aug. 1, 1958—B. F. Goodrich Chemical Co. approves design and construction of a new vinyl chloride process at Calvert City.

Sept. 1, 1958—BFG management approves RW-300 computing-control system.

May 1, 1959—Plant startup, without computing-control.

Dec. 2, 1959—RW-300 is delivered to Calvert City, with partial program.

Jan. 13, 1960—All basic field modifications completed, BFG personnel complete programming, and computer is accepted from TRWP.

NEW YORK—

The first computer control system for a chemical process, at B. F. Goodrich Chemical Co.'s Calvert City, Ky., plant, went on stream in early January. The apparent ease with which this job was accomplished and the salutary system performance refute some misconceptions about computing-control. One impressive fact, for instance, has been the lack of trouble with the digital computer — a Thompson-Ramo-Wooldridge Products Co. RW-300— during its time in service. Experience to date indicates the computer is much more reliable, by at least a factor of 10, than the conventional process instruments and devices tied in with the system.

Goodrich chose its vinyl chloride process as first for closed-loop computer control. An acrylonitrile process, a plant completely separate from the vc plant will eventually be under control of the same RW-300 computer. (For the time being, the digital computer also performs what amounts to off-line solution of simultaneous equations to reduce mass spectrometer readings to analyses of up to 29 components.)

• **System justification**—The direct out-of-pocket cost to Goodrich has been about $225,000 for the total system (see insert), with the expenditure expected to be returned, an economics study showed, in three or four years. This justification is for the vinyl chloride plant only. The acrylonitrile process study indicated even better payout potential, with little added cost for the control system. The payout for the vc part of the installation comes from expected reduction in materials reprocessing cost, from better stability in controlling reactor conversion, and from improved efficiency permitting continued rated production but at less cost for raw materials. Although no direct payout can be attributed to it, the experience gained by BFG personnel on the project was held to be of value to the company.

Although process information remains confidential, Goodrich disclosed what they did in the way of integrating the computer, the instruments, and the process. From an instrumentation point of view, the system is straightforward. Sixty process-variable measurements are made at the vinyl chloride process and fed into the computer. The computer calculates eight output signals (actually only five were in use early in March). The outputs serve as setpoints for conventional Foxboro pneumatic controllers. The controllers in turn vary the final control elements in the process streams.

Of the 60 inputs, 28 come in as low level millivolt signals from thermocouples measuring temperatures, and two are amplifier test signals. Amplifiers raise the millivolt signals to 1 to 10 vdc for compatibility with the RW-300 analog to digital converter at the computer input.

Thirty high level signals represent process pressures, flows, column differential pressure, and temperatures. These measurements first occur as 3- to 15-psi signals but are converted by 30 Foxboro pneumatic to electric transducers to 2- to 10-vdc inputs before entering the computer.

After the computer calculates the output values, they are stored on a track in the computer's drum memory. The digital signals from the output track are automatically picked up by the digital to analog converter whose output then appears as 0- to 5-vdc signals. Taylor e/p transducers convert the electrical signals to 3- to 15-psi signals going to cascade subpanels which establish the setpoints for the controllers.

• **A neat arrangement**—Goodrich uses a novel scheme for taking process temperature measurements—ranging from 30 to 1,400 deg F—with thermocouples and converting the millivolt signals to equivalent temperature units. Temperatures above 400 deg F are measured with platinum/platinum-rhodium thermocouples, those below 400 with iron/constantin couples. Two reference junction ovens are maintained at 150 and 250 deg F, thus yielding thermocouple reference signals at 150, 250, and—in series—400 deg F. This means there are six possible interpolating and range equations for any one type of thermocouple. Because of this, millivolt signals can be linearly interpolated with good accuracy, thus avoiding a lengthy computer program incorporating a second or third degree relationship between millivolts and degrees. Actually, the installation uses four equations for i/c and one for pt/pt-rh couples.

The more difficult part of the computing-control project was developing the mathematical model of the process, specifying such computer functions as scanning and logging, and programming the RW-300. To implement this task, BFG separated installation problems from the math model study.

• **Installation group**—Goodrich assigned two instrument engineers from its central engineering department (Cleveland) to work part time in designing the graphic control panel. In addition, for each variable, the design people gave the computer programmers the factors to convert in-

Control room for the first chemical process operating successfully under digital computer control. RW-300 digital computer and an array of conventional pneumatic instruments and transducers control B. F. Goodrich Chemical Co.'s vinyl chloride monomer process at Calvert City, Ky.

strument signals into appropriate engineering units represented by the measurements. Also, BFG had one Calvert City instrument engineer participate in decisions involving instrumentation selection and installaton.

TRWP assigned one man to serve as project engineer for the system. He assumed responsibility for expediting hardware procurement and computer programming, assuring compatibility of instrument signals, specifying computer functions, installing the computer, and training operators.

Pneumatic to electric input transducer racks were assembled by Foxboro and shipped to Calvert City. Individual Taylor electric to pneumatic output transducers were assembled by BFG instrument engineers at Calvert City. From this point on, process variable transmitters and graphic panel installations, as well as necessary hookups, were handled by BFG instrument mechanics as if the job was a normal process instrument installation.

• **Mathematical model study group**—To this group Goodrich assigned two scientific personnel, James Madigan and Robert Carroll, from its Avon Lake (Ohio) Development Center. TRWP devoted engineering manpower as the need arose during the project. A BFG man came in from the Louisville pilot plant to contribute his know-how to the study group. TRWP performed a digital simulation on its IBM 704, using pilot plant data first and later on using production data, to solve the kinetics aspects of the vinyl chloride math model.

TRWP engineers worked closely with Madigan on the method of optimizing—a technique not yet revealed since it would disclose proprietary process information—to be carried out by the RW-300. Furthermore, Goodrich on its own developed "20-min control equations" and programmed these later into the computer. TRWP trained both Madigan and Carroll in RW-300 programming.

The mathematical model entails both kinetics and physical separation data obtained from pilot plant and production plant runs. The data was reduced by off-line regression analysis computation to establish a reasonable and workable model for the RW-300. The math model as programmed into the control computer is in algebraic form, the terms of which are correlated with process conditions:

$$Conversion = b_o + b_1 f_1(Temp) + b_2 f_2(Flow) + b_3 f_3(Pressure) + \ldots$$

The factor b_o is changed every 8 hrs to a new value which is based on information gleaned and stored by the computer during the preceding hour. Other equation factors change so slowly that to obtain new, more accurate values requires data taken over a period much longer than 8 hrs. Reduction of the data for new values is therefore done more efficiently on an off-line digital computer. Thus the RW-300 incorporates an adaptive feature by changing b_o, but it does no on-line regression analysis.

The mathematical model also includes simple equations like material balances derived by analysis rather than test. Here, process measurements and the computer-stored material balance are used to calculate various stream compositions and reactor conversion efficiency. The model is based on economics, maximizing profit and minimizing cost.

Stated another way, the mathematical model provides two major functions. The first is called the "8-hr optimizing equation" which tells how to best run the plant based on monthly production goals (which may be changed by management several times a month). The computer keeps track of past production and the time left in the month to make the remaining quantity. Using this information the computer determines the needed production rate.

The "20-min control equations" measure how well the plant is running in trying to meet the demands set by the optimizing equation and change the process variables as needed to reach the optimum based on existing process conditions. The control equations adjust reactor feed rate and heat input to maintain a constant conversion at the optimum value. In addition, the control program determines which way to adjust distillation column temperature at the controlled location to maintain product specs with minimum losses.

• **Role of off-line computing**—Goodrich employed a Bendix G-15D general purpose digital computer to good advantage during the early phases of the computing-control project. First, a library of physical separation programs for the vinyl chloride process, already available for the G-15, aided in developing the math model for the RW-300. Then BFG used the G-15

COST OF COMPUTING-CONTROL

Computer and input/output hardware (TRWP)	**$150,000**
Additional instrumentation (transducers, cascade subpanels, etc.)	**25,000**
Programming and engineering charges by TRWP	**50,000**
	$225,000

Instrument engineering design (in Cleveland) costs attributable to computing-control were relatively small and carried as part of usual instrument design costs. Cost of BFG engineering personnel time spent on computing-control project carried as part of normal research and development cost. Thus $225,000 was paid to outside companies.

MUIRHEAD

GEARHEADS

Backlash after 500 hours' running!
Less than 45 mins.

These gearheads are designed to mount on the front of standard Bu-Ord, SAE, and RAE size 11 motors, and can accommodate the different shaft lengths of these types. They have the same overall diameter and mounting arrangements as the motors to enable them to be mounted in a similar manner. Types are available modified for use with size 08 or size 10 motors, or on their own as speed reducers. In the design particular attention has been paid to robust construction and long life, ball bearings are used throughout and the materials and dimensions of the gears have been chosen to give minimum amount of wear.

PERFORMANCE SPECIFICATION

INPUT. The input gear meshes with the 13 tooth 120 DP. pinion of either standard Mark 14 motors, size 11 motors to SAE, ARP, 497 or size 11 motors to RAE, EL, 1789.
OUTPUT. The standard output shaft is splined 21 teeth 120 DP. with thread for shaft nut and drive washer. Alternatively plain shafts up to $\frac{7}{16}$" diameter may be supplied, or a 13 tooth 120 DP. pinion suitable for cascading 2 or more gearheads.

Maximum power output, torque not to exceed 80 oz in	$\frac{1}{4}$ watt
Maximum backlash after 500 hrs running with $\frac{1}{4}$ watt load	45 minutes measured on output shaft by reversing 8 oz in torque
Starting torque	0.2 gm cm
Inertia at motor shaft	0.02 g cm^2
Operating temperature range	—54°C to +100°C
Tropical exposure test DTD 10858	Withstands 28 days exposure

RATIOS. A number of ratios up to 600:1 are available as standard and these will probably satisfy most requirements:—Types G11A, 600:1; G11B, 300:1; G11C, 150:1; G11D, 60:1; G11E, 24:1; G11G, 40:1. Other ratios can be provided.

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Precision Electrical Instruments

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489

WHAT'S NEW

to simulate the RW-300 command structure for preliminary debugging of the proposed RW-300 program.

Track guarding, watchdog timing, and limiting the magnitude and rate of change of process conditions all safeguard the process. Track guarding prevents inadvertent writing into the "scratch pad" section of the drum memory—those tracks storing process measurements and computer output signals in digital form. For data to enter any portion of the memory, the operator must have first inserted a connector plug for the appropriate tracks. As an additional safeguard, to write in the scratch pad, the program permits data to be entered only on those tracks carrying process flow accumulations and output signals. When writing is finished, the program sends another signal to restore the electrical guard.

• **Getting the system started**—The system went on stream with relatively little trouble, although minor difficulties did occur from time to time. For one thing, the input transducers had to be recalibrated in Calvert City because they were jogged during transit from the vendor. The RW-300, too, loosened up a bit in its crosscountry trek from Beverly Hills. Restoration of modules and cables, as well as replacement of several transistors and diodes burned out during initial hookup, took about two days.

Once debugged and the programming completed, the computer has not taken itself out of service because of internal failures. It has, however, taken itself off stream several times and reverted the process to manual control because the computer has sensed an instrument primary element failure. Fail-safe provisions in the program sense out-of-range signals from instruments.

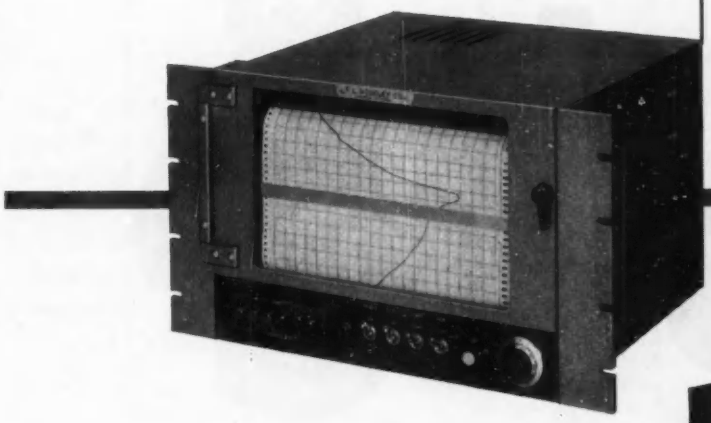
Operator and instrument mechanic acceptance of the computer control system has been good. Operating management has long been exposed to the benefits of off-line computing as an aid to process operation and improvement. The number of process operators remains the same; their duties have been redefined.

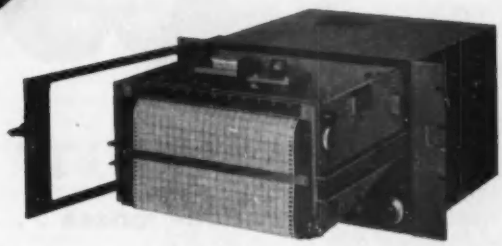
TRWP has contracted to supply Goodrich with computer maintenance, with a service engineer to be available or on-call 24 hrs a day, 7 days a week, for two years. During this period, however, a Goodrich instrument engineer will be trained to maintain the computer, taking about one-fifth of his working time.

—Harry R. Karp

Ever see a
NEW STRIP-CHART RECORDER
that offered you all this:

- 6 push-button variable chart speeds
- Transistor speed switching; no gears
- 0.05% full scale sensitivity
- 0.2% resolution and accuracy
- Local or remote chart or pen control
- Continuous span voltage, 5 mv to 100 v





Glass door protects chart; ball-bearing carriage rolls out for easy chart or circuit access

Six chart speeds, 2, 4, 6, 8, 15 and 60 in/min selected instantly by front panel push buttons.

The all-new Moseley Model 80A Strip-Chart Recorder is a precision instrument providing greater versatility and convenience than any commercial strip-chart recorder previously available.

Model 80A gives you instant selection — through transistor switching — of 6 chart speeds. All other function controls are grouped in a newly convenient array on one front panel. The input range of 5 mv to 100 v is covered in 10 steps, or by vernier for completely continuous span voltage control. Input resistance is 200,000 ohms/v through 10 v, 2 megohms on higher ranges. Full range zero set, pen speeds to 0.25 sec full scale, chopper amplifier, standard 120′ rolls. For 19″ relay rack. $1,750.00.

NEW! TYPE F-2 LONG-STRIP CURVE FOLLOWER

New-concept curve follower tracks, converts ordinary recorded trace to electrical energy; requires no metallic inks or re-drawing. Employs unique photoelectric-oscillating mirror principle: permits digital output for tapes, cards, etc.

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Pioneer and leader in X-Y and Strip-Chart Recorders

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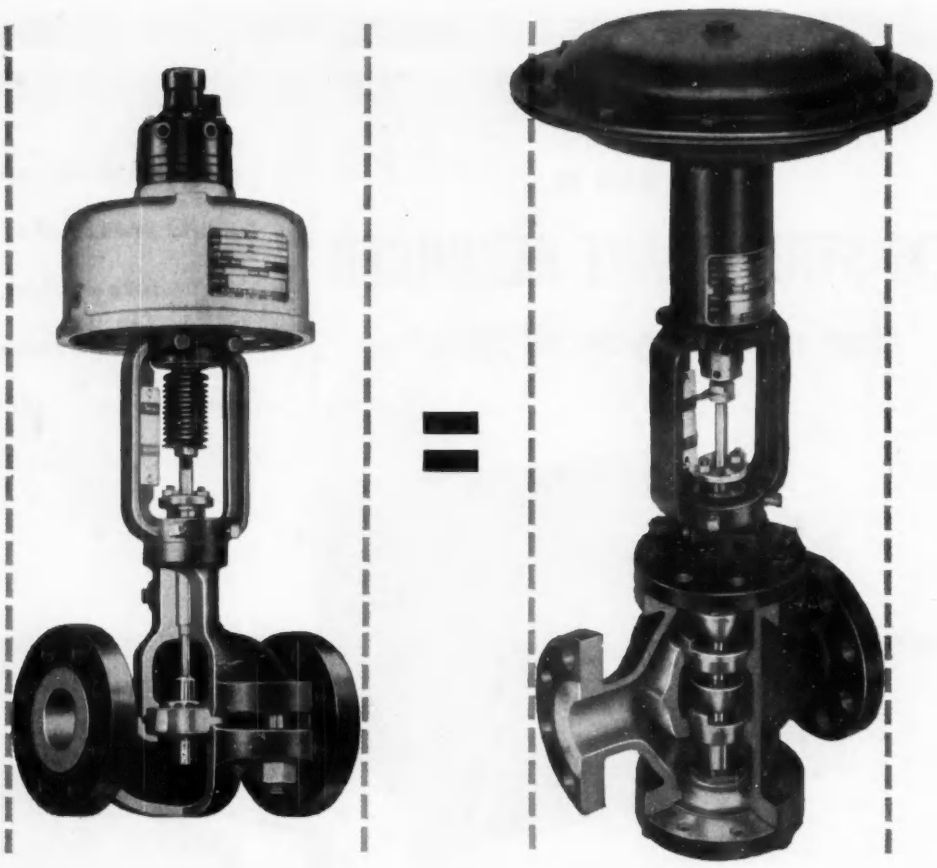
CIRCLE 23 ON READER SERVICE CARD



"FIT" Companions

reduce costs . . . increase valving flexibility

With face-to-face dimensions to I.S.A. standards, K&M split body valves are interchangeable with K&M regular globe-body diaphragm valves (and with all standard makes of diaphragm valves).

This *exclusive* feature of the K&M split body design enables you to make significant reduction in your plant inventory investment of replacement valves. It gives you highly desirable flexibility.

Additional flexibility is provided in the K&M split body valve itself. Interchangeable. unitized construction makes it possible to develop 432 different valve combinations from a single split body.

In a matter of minutes you can make the body reverse or direct-acting; switch the operator to dome, diaphragm, or handwheel; change the seat ring to one of several types; recharacterize by selecting a different plug; substitute the replaceable, rotatable flanges; convert from globe to angle type.

The K&M split body valve fits your existing piping and fits your budget.

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Write for Catalog 132 completely describing the valve that brings the split body idea to its fullest development.

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CIRCLE 23 ON READER SERVICE CARD

WHAT'S NEW

New Process Develops Movie Film in 60 Seconds

Movie Camera set up for Rapromatic quick processing.

Broad application in data processing is seen for a new chemically saturated paper that can develop motion picture film in a minute. Cost competes with commercial processing.

SYOSSET, N. Y.—Motion picture film can be processed in 60 seconds in a standard film magazine with a new chemically saturated paper which was put into production last month. The rapid processing produces a negative quality as good as fast commercial development (see pictures below) and costs about the same. Called Rapromatic processing, it is the development of Specialties, Inc., and relies on conventional silver halide chemistry—the conversion of light-struck sensitized silver halide compound to metallic silver.

Its application: wherever almost instant viewing of motion pictures is required—in motion picture data recording, monitoring TV scan, photo instrumentation (ground or airborne), television and news photography, photo patrol of horse races, and sporting events photography. It looks particularly promising for airborne applications where the sloshing or spilling of developing and fixing chemicals is a serious problem.

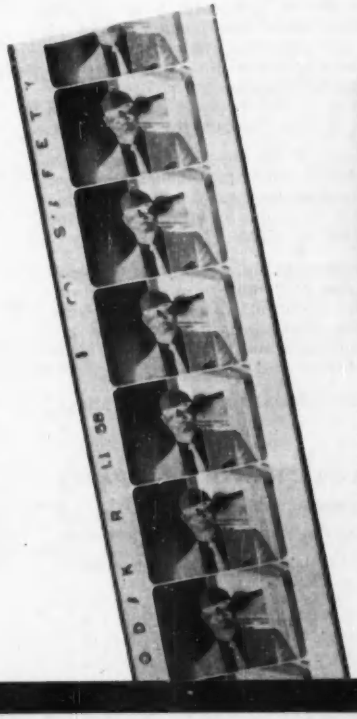
Rapromatic appears to be the "Polaroid of the motion picture." The photo above shows how it works with a standard 16 mm movie camera and a standard film magazine. When the film is loaded, it is threaded onto a takeup spool in the magazine; at the same time a roll of Raproroll, the chemically saturated paper, is loaded onto the top spool of the film magazine and is also threaded onto the same takeup spool as the film. As soon as the covers (not shown in the picture) are closed on the camera and the magazine, the equipment is ready to take pictures.

As photos are taken, the magazine takeup spool interleaves film and Raproroll. A pressure bar attached to the magazine, the only modification required, forces the film and paper into close contact so that the processing solution is in intimate contact with the film. Development starts as soon as the film contacts the Raproroll paper, 60 seconds later the film is ready for viewing.

• **Monobath**—As a starter, Specialties, Inc., will saturate the paper with a monobath solution. That means one solution contains both developing and clearing agents. But with a monobath the developed film is not permanent; it will last about 30 days without deterioration. If the film is to be kept longer than 30 days it should be treated sometime before the deadline with a special permatizing solution.

The developer completes the reaction in a given time for a given temperature. Longer developments than 1 min don't injure the quality of the negative. An increase in temperature, however, can shorten the time of development. The 60-sec figure is for a temperature of 70 deg F.

In those applications where 60 sec is too long to wait, the film can be viewed in a shorter time provided that a little bit of film fogging is not objectionable. In a demonstration, CtE viewed films within 20 sec after they



A strip of 35-mm film rapid processed by Rapromatic and an enlargement (made by conventional darkroom techniques) of Associate Editor Lew Young shows the negative quality.

Here's an

EYEFUL of technical data on precision resistor and potentiometer wire

Two new catalog-manuals containing complete information on

TWO NEW HOSKINS 800 OHM ALLOYS

If you make potentiometers or precision wire wound resistors, these manuals are meant for you! They're loaded with helpful technical information—show all physical properties and electrical characteristics, list bare and enameled wire specifications. And they contain much useful application data compiled especially to help you produce more and better control components with these two new performance-proved alloys:

Chromel-R: A modified 80-20 type nickel-chromium alloy possessing electrical resistivity of 800 ohms per cmf at 20° C., low temperature coefficient controlled within 0 ± 10 ppm per °C.—plus exceptional linearity and stability from −65° to +150° C.

Alloy 815-R: A lower density, higher resistivity fe-cr-al material that gives you 14% more ohms per pound. Has good strength and ductibility, excellent resistance to wear and corrosion. Resistivity is 815 ohms per cmf at 20° C., temperature coefficient 0 ± 10 ppm per °C. in the range from −65° to +150° C.

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WHAT'S NEW

. . . the big problem is how to contain the processing solutions without free liquids . . .

were photographed. The results were clearly readable though the film fogged during the reading.

For special applications, Specialties plans to introduce two-stage rapid processing. This entails using two Raprorolls, one for developing and one for fixing the film. One disadvantage to the present monobath solution is that the developer has to be compounded for the particular film emulsion being used.

Starting in April, Specialties will offer two different kinds of Raproroll: one to process Eastman Kodak Plus X movie film, the other to develop Dupont 931 film. Eventually, Specialties expects to have Raprorolls for those movie films most frequently used in applications that need rapid processing.

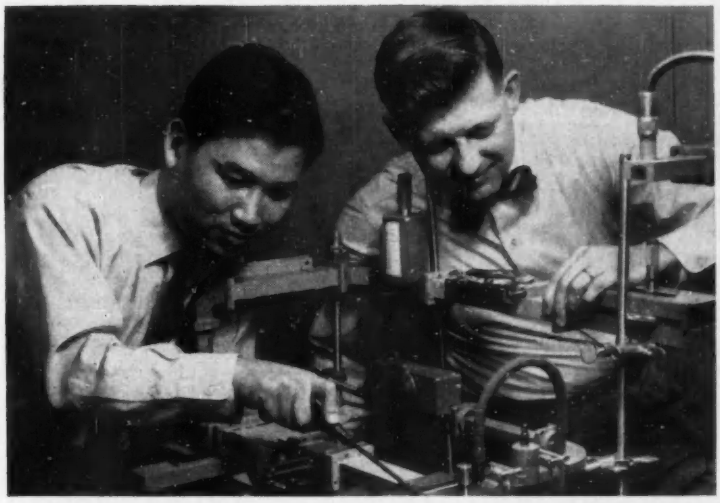
• **Starting clean**—Rapromatic processing is a unique addition to the product line of Specialties. The company, started just before World War II to design and manufacture industrial controls, switched to making military gear after Pearl Harbor. It has concentrated on building specialty items such as special aircraft instruments and electromechanical products.

In 1958, because of possible military applications, Specialties President Stephen McClellan bought the Rapromatic process from Kenyon Instrument which had been experimenting with it for almost seven years. Now Specialties sees Raproroll leading the company back into industrial markets.

In rapid processing the major problem is how to contain the developing solutions and eliminates free fluids. Rapromatic is called a wet web process because the developer and fixer is in a water-like solution contained in a web of paper. (Historically, the wet web process goes back to 1913). Other types of rapid processors use tanks to contain the liquids or use viscous materials. For example, the famous Polaroid system for the rapid processing of still photographs uses a viscous monobath. When the Polaroid film is moved after an exposure has been made, a package containing the developer is broken, and a metering applicator smooths the viscous liquid across the film evenly.

Specialties' big contributions to rapid processing have been the selection of the proper grade of paper to hold the solution and the

THE IDEA THAT GREW FOR 100 YEARS



At Bell Laboratories, M. Uenohara (left) adjusts his reactance amplifier, assisted by A. E. Bakanowski, who helped develop first suitable diode. Extremely low "noise" is achieved when certain diodes are cooled in liquid nitrogen.

First practical diode for amplifier, shown here held by tweezers, was jointly developed by A. E. Bakanowski and A. Uhlir.

How basic scientific ideas develop in the light of expanding knowledge is strikingly illustrated by the development of Bell Laboratories' new "parametric" or "reactance" amplifier.

Over 100 years ago, scientists experimenting with vibrating strings observed that vibrations could be amplified by giving them a push at strategic moments, using properly synchronized tuning forks. This is done in much the same way a child on a swing "pumps" in new energy by shifting his center of gravity in step with his motion.

At the turn of the century, scientists theorized that *electrical* vibrations, too, could be amplified by synchronously varying the *reactance* of an inductor or capacitor. Later amplifiers were made to work on this principle but none at microwave frequencies.

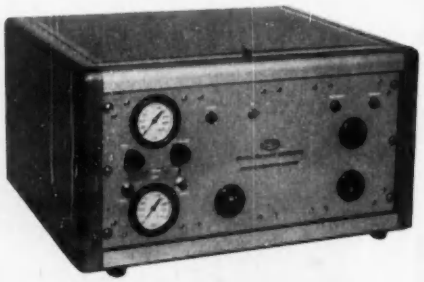
Then came the middle 50's. Bell Telephone Laboratories scientists, by applying their new transistor technology, developed semiconductor diodes of greatly improved capabilities. They determined theoretically *how* the electrical capacitance of these new diodes could be utilized to amplify at *microwave* frequencies. They created a new microwave amplifier with far less "noise" than conventional amplifiers.

The new reactance amplifier has a busy future in the battle with "noise." At present, it is being developed for applications in tropospheric transmission and radar. But it has many other possible applications, as well. It can be used, for instance, in the reception of signals reflected from satellites. It is still another example of the continuing efforts to improve your Bell System communications.

BELL TELEPHONE LABORATORIES

WORLD CENTER OF COMMUNICATIONS RESEARCH AND DEVELOPMENT

BREAKTHROUGH IN THE SCIENCE OF PRESSURE CONTROL



digital-servo
reliability
crystal-determined
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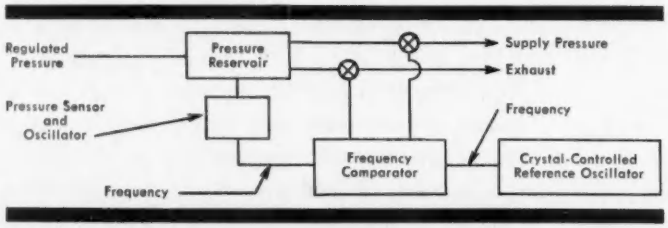
WIANCKO'S Q3700 SERIES DIGITAL PRESSURE GENERATOR

This system, employing unique digital-servo concepts, provides instant selection of a pneumatic pressure accurate to ±0.05 PERCENT.

Pressure in a reservoir is measured and converted to a precision frequency. This frequency is compared with a selected reference frequency. If the frequency from the pressure sensor is high with respect to the reference frequency, the comparator produces a difference frequency in the form of pulses. These pulses then drive momentary exhaust valves until the pressure drops to the pre-selected value. When the frequency is low, error signals are produced which operate momentary pressurizing valves. The Q3700 is the best answer yet to pressure control and calibration problems.

Ideal for:

- *Programming precision pressure/time functions*
- *Automatic end-to-end calibration of data and telemetering systems*
- *Rapid calibration of pressure devices*
- *Ground checkout of instrument and control systems*



For complete information please request Product Bulletin 111

WIANCKO
ENGINEERING COMPANY

Precision with lasting reliability

255 North Halstead Avenue • Pasadena, California

WHAT'S NEW

compounding of mono-baths.

Today Specialties feels it is ahead of the field on paper and chemistry. The secret of Raproroll, says Assistant to the President E. W. Richardson, is impressing "the *right* compound in the *right* material of the *right* thickness with the *right* saturation".

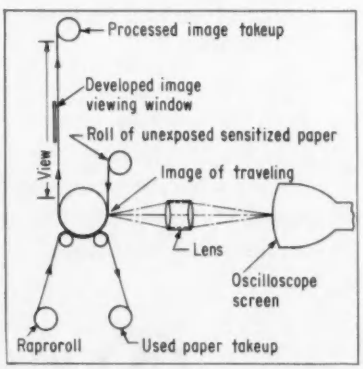
Raprorolls are being packed in hermetically sealed aluminum foil packages to have a shelf life of one year. Exposure to extremes of low and high temperature appear to have no affect on the life or efficacy of the processing solution.

• **New products galore**—To accompany the Rapromatic process, Specialties has plans for a flock of new products. For example, already on the drawing boards is a table-top rapid processor which will process and permanentize 100 ft of film in 9 min. Such a unit is designed for applications such as high speed photography where the film is generated at rates faster than can be processed in a conventional film magazine.

Another new product is an instant cathode ray tube recording camera. This camera will permit viewing prints of images from the cathode ray tubes in 5¼ sec. And it permits a continuous record to be made (see below).

• **New smell for Skunk's Misery**—Production facilities for Raproroll have been established in Specialties' plant at Skunk's Misery Rd. in Syosset, Long Island. Custom-developed rolls designed to process special films will be made in the laboratory in which Raporoll was perfected under the guidance of project engineers Seymour Shreck and Gilbert Haines.

Next big job for the Rapromatic team: improving Rapromatic so that it can produce a positive, too. Present system is limited to negatives.

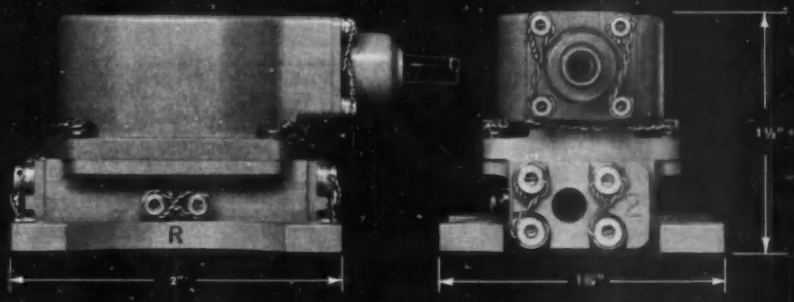


Block diagram of the rapid processing cathode ray tube camera.

NEW

0.32 lb (TOTAL WEIGHT)

MECHANICAL FEEDBACK
DRY MOTOR
LOW FLOW CONTROL
SERVOVALVE



"INDUSTRY STANDARD MOUNTING DETAILS"

For critical applications where outstanding performance must be achieved with a minimum of weight, Moog offers the Series 30 Servovalve. These valves utilize the proven first stage of the standard Series 31 and 32 Moog valves, and are now available with rated flows to 7 cis at 1000 psi valve drop.

WRITE FOR PRODUCT BULLETIN 113

from **MOOG**

MOOG SERVOCONTROLS, INC.

PRONER AIRPORT; EAST AURORA, NEW YORK

INSTANT INDICATION

of Voltage Tolerance with NLS Series 50 Comparators

NEED TO DETERMINE IF INPUT VOLTAGES ARE WITHIN PRESET LIMITS? Within 90 milliseconds, NLS transistorized voltage comparators indicate voltage tolerance through colored bulbs . . . and transmit go/no-go commands to electrical control and warning systems. Here are complete voltage comparison systems in single, compact packages — ready to use in a wide range of applications in automatic go/no-go testing, decision making, and automatic control. Model 50 is for manual limit setting — Model 51 for applications where limits are already in analog voltage form. Also available are Programmed Comparators for remote control of limits in automatic systems. Write NLS.

Model 50 SPECIFICATIONS: Ranges: ±9.999/±99.99/±999.9 volts . . . ±0.01% accuracy easily checked against external standard cells . . . 10 megohms input impedance . . . threshold sensitivity: ±0.005% of full scale, each range . . . indicating speed: 90 milliseconds . . . 3½" high by 15¼" deep for 19" rack.

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non-linear systems, inc.

DEL MAR (SAN DIEGO), CALIFORNIA

NLS — The Digital Voltmeter That Works . . . And Works . . . And Works!

Cashing in on New Components

New components are responsible for two unusual resistance welding control systems announced last month.

CHICAGO—

Relying on new but quite opposite components, two new control systems designed for resistance welding equipment were unveiled last month:

▶ In Chicago, International Research Associates demonstrated a small lightweight welding package, made small because it gates electric current with silicon controlled rectifiers.

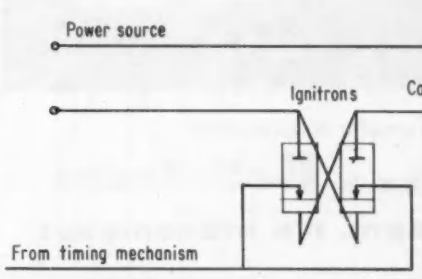
▶ In Detroit, Robotron Corp. announced a "spike power" welding control unit, made possible by a newly developed General Electric Co. coaxial ignitron tube. Both units are designed to make it easier to perform welding throughout a plant, requiring no special electrical service.

• **Putting the SCR to work**—IRA's new unit weighs only 60 pounds although its nominal output is 300 amps at 25 volts. That's a weight/output ratio of 3.2 ounces per amp, compared to about 1 pound per amp in a conventional welding control.

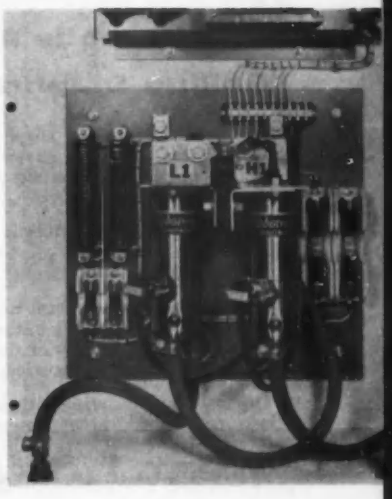
The circuit that makes such a weight saving possible is shown in the block diagram below. Silicon controlled rectifiers are gated to allow the current to flow through the welding transformer for a time sufficient to produce 300-amp welding current.

Line voltage passes through a pair of SCR's, through the welding transformer primary, through a current feedback transformer winding, and back to the line. When the circuit is open, the potential across the welding transformer secondary is 32 volts. When the welding arc is struck, current flowing through the feedback transformer increases sharply, causing a voltage swing which is applied to a phase shifter. Adjusting the phase angle of its output, the phase shifter applies gating pulses to the SCR's to allow the current to flow in the welding transformer.

Controlling the firing angle of the SCRs thus controls current flow through the transformer. When the current flow increases, the phase shifter increases the firing angle and reduces the time current flows during one cycle of the line voltage sine wave. In effect this action reduces the root-mean-square voltage through the welding transformer and solves one of the key problems of resistance welding: how to maintain a constant welding current.

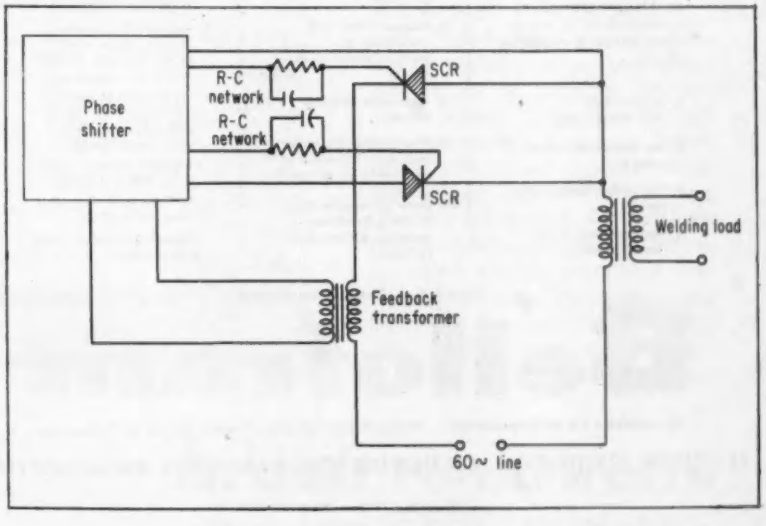


Ignitron control.



Normally, welding current variations are caused by changes in the distance between welding electrode and work. As the electrode moves towards the work, the arc—an ionized stream of metallic particles—shortens, decreasing arc path resistance. When resistance decreases, of course, current flow increases. Because of its constant cur-

Silicon controlled rectifiers in welding control.



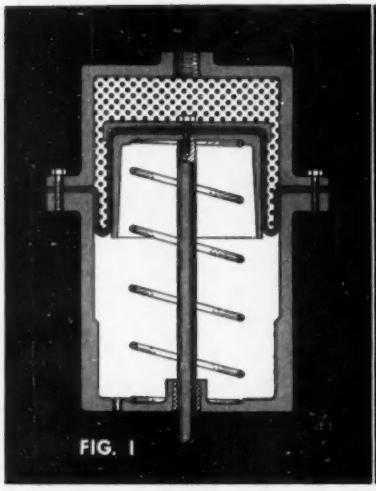


FIG. I

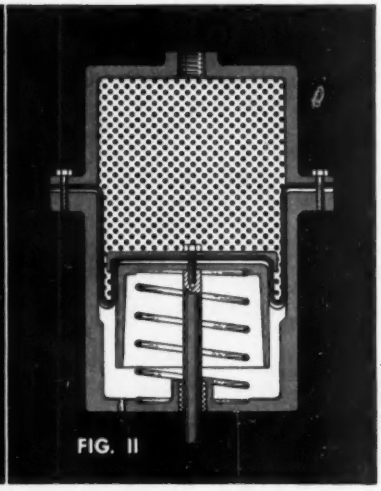


FIG. II

For Hydraulic and Pneumatic Applications

Nothing rolls like a Bellofram Rolling Diaphragm. It's frictionless!

The Bellofram Rolling Diaphragm provides ultrasensitive response in hydraulic or pneumatic devices where frictionless, long-stroke action in small-diameter configurations is required . . . and where flex life of millions of cycles is necessary.

These desiderata are achieved through the *rolling* action of a flexible thin-sidewall diaphragm consisting of a high-tenacity fabric overlay embedded in elastomeric material.

Fig. I shows how Bellofram Rolling Diaphragm conforms to the piston. Fig. II shows how, as the piston descends under pressure, the diaphragm *rolls* off the piston's sidewall and onto the cylinder's sidewall in a smooth, continuous, frictionless movement.

The Bellofram principle can be applied widely in actuators, pumps, instruments, seals, accumulators, fluid dampers, etc.

Which of these advantages are you looking for?

To the designer confronted with situations for which conventional bellows, O-rings, or cup packings are inadequate, Bellofram Rolling Diaphragm offers a constellation of advantages found in no other product:

1. Friction-free (low hysteresis).
2. No break-out friction effects.
3. Completely leakproof device.
4. Constant area in all piston positions.
5. Almost infinite flex life (millions of cycles).
6. Sensitivity to extremely small pressure changes.
7. No mechanical spring gradient.
8. Compatibility with practically all environmental gases or fluids.
9. Automatic de-icing action.
10. Free positioning with complete relaxation at any point in its stroke.
11. Does not require close machine finish tolerances on pistons and cylinders.
12. Freedom from abrasive wear.
13. One hundred stock sizes. Four mounting configurations. Special types and sizes designed to order.
14. Excellent temperature stability, from —85°F. to 550°F. (from —120°F. to 700°F. in some cases).

Wide range of working pressures: 1 in. H_2O to 500 psi (up to 1200 psi in some cases).

Effective pressure areas from .028 to 108 sq. in.

Cylinder bore diameters from .25 to 12 in.

Extended range of stroke (.01 to 12 in.).

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WHAT'S NEW

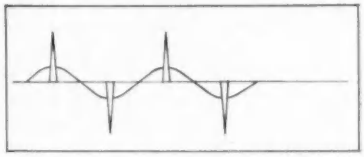
rent control, the IRA unit allows constant welding temperature for any arc length.

The firing angle method of control also provides short circuit protection. If a short circuit occurs, the firing angle of the SCR will automatically increase to nearly 180 degrees, thus shutting off current flow.

• **Fired by networks**—To fire the SCR's, IRA employs two resistor-capacitor networks. The networks modify the line voltage sine wave into a fast-rise narrow wave form which is required to gate the SCR's properly

• **Ignitron magic**—A newly developed ignitron tube gives Robotron's new spike power welding control the capability of high current, short duration electrical pulses of high reliability.

In spike welding (see diagram below), welding current is applied in



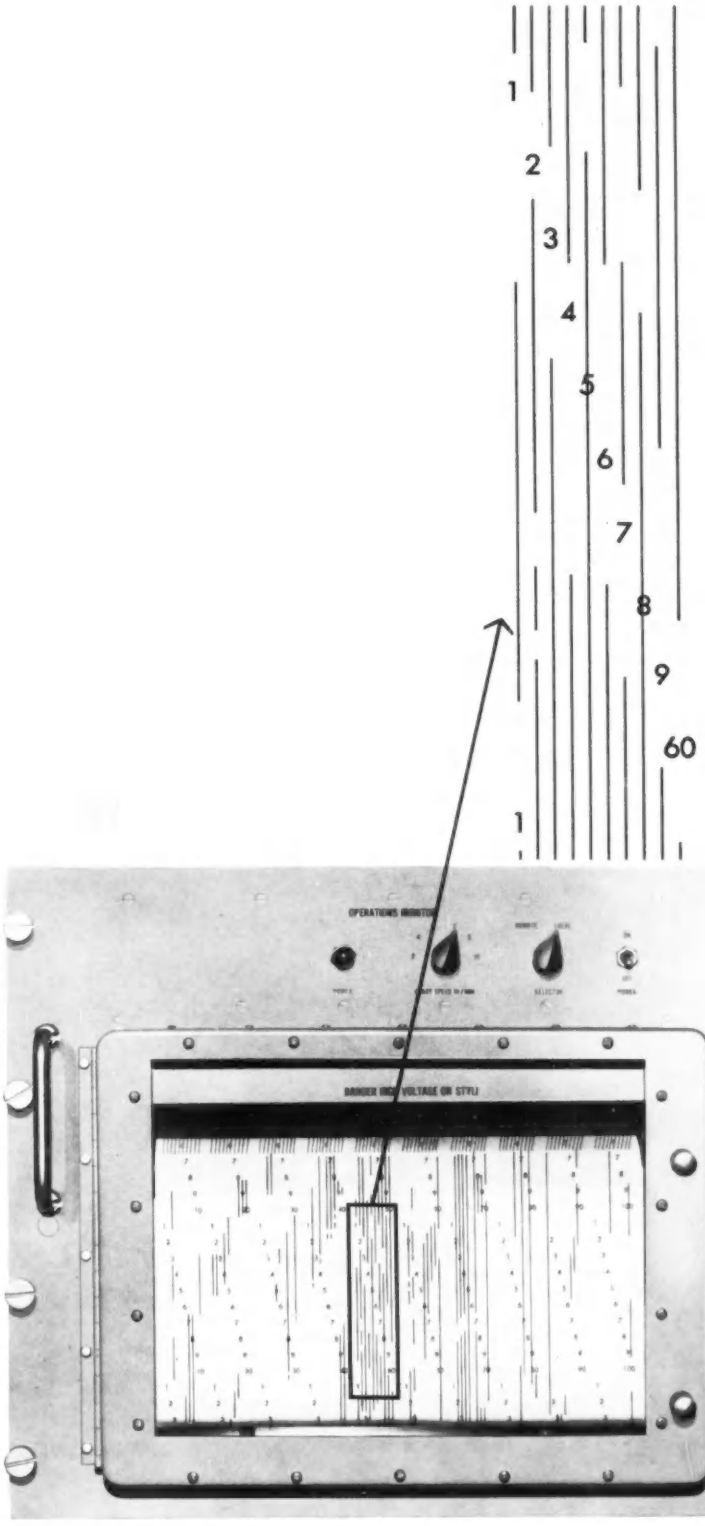
short bursts of power at intervals of one burst every half cycle of time. Normally such pulses are developed by capacitor discharge units which require at least one full second to recharge, limiting speed of operation to one power pulse per sec.

Applying a new ignitron tube, Robotron was able to develop a capacitor discharge system which can generate up to 120 spikes per sec—without misfiring, the bugaboo that has retarded rapid pulse resistance welding.

Each pulse of power has a duration of about 1 millisec. A phase shifted tube is arranged to delay the firing until the 90-deg point is reached in an ac sine wave. As soon as the tube fires, the capacitance is rapidly charged.

Time for charging the capacitor determines the width of the spike. If a large inductance is applied, the time for charging is long and the pulse widths, wide; with a small amount of inductance, the pulse will be of higher amplitude and of shorter duration.

Short duration of the welding spikes means less heat generation around the weld zone. As a result, material can be handled right after welding. Robotron claims the equipment can make 500 welds per min even on vinyl clad and lacquer coated steels which normally have to be handled carefully.



insight at 4 milliseconds

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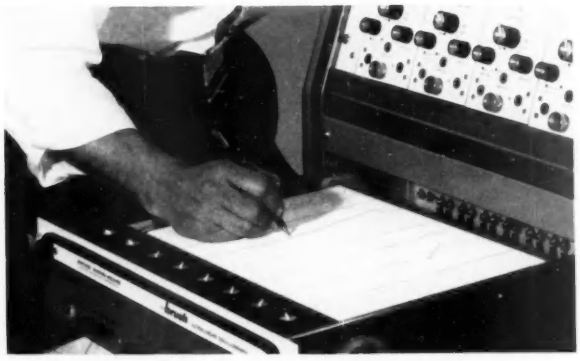

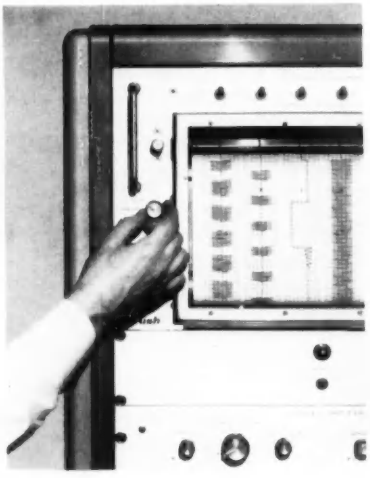

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New Computers Debut

Bendix adds a big brother to its G-15 machine, the G-20; Monroe introduces a desk-size computer unit.

Computer makers started last year introducing what they called the "second generation" of general purpose digital machines for business data processing and scientific problem solving. These are fast, solid state computers. Since that time there has been a flood of new machines introduced such as the Burroughs ElectroData 220, the IBM 7070, 7080, and 7090, the Remington Rand Univac Magnetic, the RCA 501, the Minneapolis-Honeywell Datamatic 800, and the Control Data Corp. 1604, and—in the small computer class—Royal-McBee's RPC-4000 and IBM's 1620. Last month the flood continued with two additional machines debuting:

▶ Bendix Corp.'s computer division introduced the G-20, a solid state big brother for the company's G-15.

▶ Monroe Calculating Machine Co., Div. of Litton Industries, introduced a solid state, desk-sized machine.

Since it was first introduced in 1956, Bendix has sold about 300 G-15 machines, a vacuum tube computer with a price tag of about $50,000. The company's new G-20 is a fast, parallel computer (meaning computation is performed in parallel, and all transfers between the computer and input-output devices are done in parallel, a whole word processed at a time), whose average selling price is over half a million dollars.

Bendix is counting on some unusual features as well as a much lower price to make its new machine competitive with such computers as the IBM 7070, the RCA 501, and the CDC 1604. For example, Bendix will offer floating point arithmetic (for scientific problem solving) at very little additional cost.

But probably Bendix's biggest feature is the control buffer which can be purchased as optional equipment. Containing a 1024-character (eight-bit groups) core memory, the buffer can control peripheral equipment while the computer is performing computations. The result is that peripheral equipment on the G-20 can be operated on-line or off-line with no sacrifice in computer capacity.

The G-20 has been designed so that the machine's capacity and capability can be expanded easily. The high speed control processor can be enlarged to handle increased computation. The central core memory can be expanded up to 32,000 words of storage from its nominal 4,000-word storage. And additional control buffers can be added (at a cost of about $30,000 each) to control the performance of additional input/output equipment.

A typical commercial application might have: one central processor, one control console, four magnetic tape units, one high speed line printer, two control buffers, and two card and printer couplers. Selling price: about $600,000.

• **Monrobot**—A quite different kind of machine is the Monrobot Mark XI, which Monroe has introduced. Its selling price is $24,500.

Inputs to the Monrobot XI can be from punched tape, punched cards, electric typewriter, teletypewriter, or number keyboard. Outputs may be to punched tape, cards, typewriter or teletypewriter.

Average computational speed is about 5,000 operations per minute. Its memory, a magnetic drum, can store 1,024 32-bit words. And the Monrobot is a serial machine (as opposed to Bendix's parallel operation).

Monroe envisions its desk-sized computer being used for a variety of business data processing and problem solving. For example the machine can compute the earnings and paychecks of 800 people in one eight-hour workday. It can also handle such business work as invoicing, sales analysis, inventory control and production scheduling. Engineers could use the machine to solve differential equations and for such problems as probability analysis and linear programming.

Some Characteristics of the G-20

Addition time (fixed point)	*7 microsec (less access)*
Addition time (floating point)	*10 microsec (less access)*
Memory cycle time	*8.4 microsec*
Core memory	*4096 words (basic)*
Word length	*33 bits*

rack-mounted pneumatic control system elements

a new concept in control system engineering

CONTROLLER MODEL 91539

PROGRAMMER MODEL 91516P

Boonshaft and Fuchs servo-pneumatic control modules provide the system engineer with a new flexibility in his system development. Each module performs a separate control function; yet a combination of modules provides an integrated control system both operationally and physically: Programmers, process simulators, controllers, second reset functions, high and low clamps, power supplies, and other modules fit standard 19-inch relay racks. Tubing connectors are standardized for quick, convenient connection between modules.

Modules such as the Model 91539 Controller provide a wide margin of stability with automatic gain and automatic reset adjustments by remote 3-15 psi signals, assuring high system performance over wide operating conditions. In addition, matching high-speed pneumatic-hydraulic actuators are available. . . . For all the facts write—

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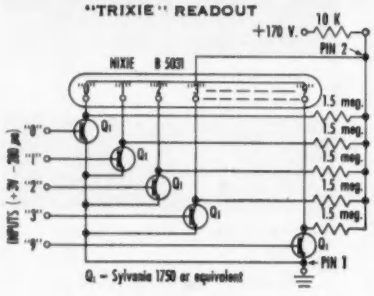

A REVOLUTIONARY CIRCUIT DESIGN MAKES THE NIXIE® INDICATOR TUBES DIRECTLY COMPATIBLE WITH TRANSISTOR CIRCUITS

New "junction protection" technique permits the use of medium voltage NPN transistors to operate the **Nixie** indicator tubes.

The result is the lowest power, all-electronic visual readout.

"Trixie" readouts are immediately available from stock.

For complete information write today for Technical Bulletin #TR 56.

ELECTRONIC CONTRIBUTIONS BY
Burroughs Corporation

For the San Francisco Commuter:

Is Automatic Transit Coming?

SAN FRANCISCO—Officials of the San Francisco Bay Area Rapid Transit District (BARTD) are putting the finishing touches to a proposal for what is likely to be the world's first fully automatic mass transit system. Estimated to cost $650 million, the high speed system will connect San Francisco with the neighboring counties of Alameda, Marin, San Mateo, and Contra Costa. If everything goes according to schedule, BARTD expects the system to start operation in 1965.

Multi-million-dollar controls will program and operate high speed vehicles in tight formation, will also tabulate passenger and financial flow data. The blueprint which BARTD will present to voters next November (for approval of a bond issue to finance the project) describes a 125-mile double-track system capable of carrying up to 30,000 seated passengers per hour at speeds averaging 45 mph. Such performance dictates a top speed on straightaways of 80 mph, with a minimum headway of 90 sec between trains.

To maintain 40 trains per hour on a single track at 80 mph, BARTD precluded human manual controls after a preliminary feasibility study. When BARTD called for informal proposals last year, the District was pleased to hear from suppliers that the system's stringent operational requirements were within the capability of present hardware. That was good news for BARTD engineers. Said one, "It makes the control an engineering problem in its entirety rather than a research and development project." In first returns, suppliers indicated delivery at a price compatible with BARTD's thinking.

In 1957 right after BARTD was established, engineers felt it would be necessary to have an operator on each train. But now thinking has shifted to completely automatic control.

• **Building blocks**—Here is what District engineers envision. The entire trackage is to be divided into blocks 1,000 feet long. Speed of trains between stops is to be controlled by coded radio signals transmitted to the lead car from trackside transmitters, each block with its own transmitter.

As a train enters a block, it would receive and respond to that block's speed signal. And it would transmit a certain amount of data back to the next three trains, information that can modify their speed control if they are approaching an occupied block.

In effect a train has to "check in" and "check out" of each block before appropriate go ahead signals are sent to the following train.

Identifying each train is accomplished by a four-digit numeric code which indicates the train's destination and length. A transmitter on the train then sends out this information continuously. Switches enroute can convert the destination digits into appropriate switching motion.

To stop the train at stations, a braking control is located on the track. It will receive destination information, convert it into braking orders.

• **Watch the doors**—At a stop, doors will open and close automatically. Length of stay in a station would normally be set at 20 seconds, but could be reprogrammed automatically. If the following train were delayed for a significant period of time, the forward train would stop longer.

Transit engineers hope to tack another dimension onto their control system by using some of it for automatic billing of patrons. Present plans: each passenger would have a commuting card which would be read by a magnetic or optical character recognition device on turnstiles to supply BARTD with continuing information about traffic which would help program trains for different times of the year and under varying weather conditions.

Next big steps for BARTD are approvals: first to win approval of each of the five county boards of supervisors. Then, the District has to win the support of two-thirds of the voters at a $550 million transit bond election in November.

—**Donald Winston**
McGraw-Hill News

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CIRCLE 35 ON READER SERVICE CARD 35

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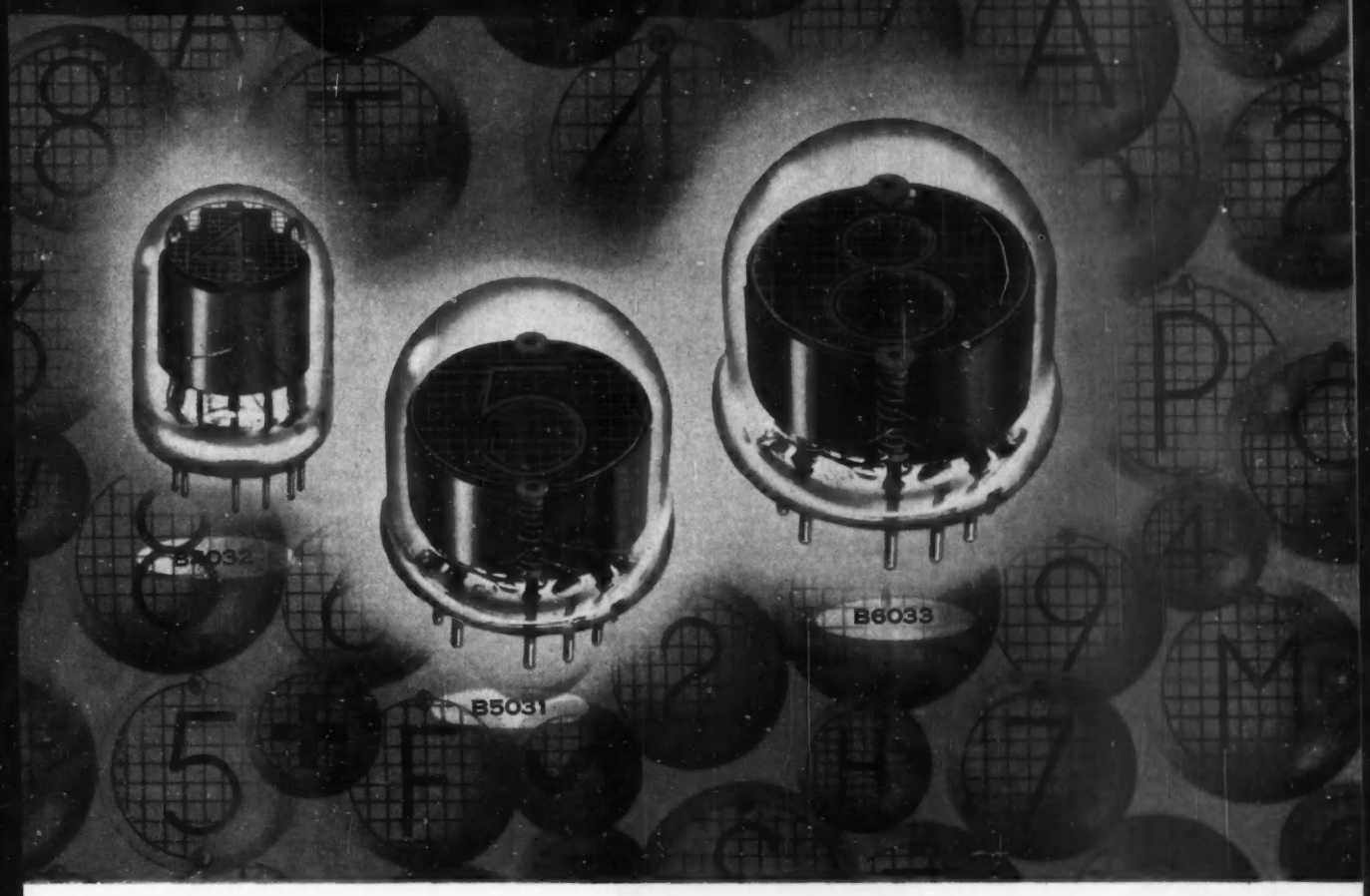
LONG LIFE NIXIE® INDICATOR TUBES



not one life failure

In November of 1957, the first Ultra Long Life **NIXIE** Indicator Tube was developed and put on life test. In 1958, the first 100 production tubes joined this life test which subjected the tubes to the most severe conditions; i.e., constant "lighting" of one of its 10 numbers. To date, **not one life failure** has been experienced. This rigid test has been in progress in excess of 10,000 hours which is the equivalent of more than 50,000 hours of normal usage.

In applications from milling machines to computers to digital voltmeters, to counters, tens of thousands of Ultra Long Life **Nixie** Indicator Tubes have been operating over one year **without a single life replacement.**

- Lowest Cost — Check low quantity prices
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- All Electronic
- Longest Life

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WHAT'S NEW

Will the Tunnel Diode Fit into Control?

Star of the Solid State Conference in Philadelphia was the Esaki diode. But despite the enthusiasm of electronic engineers, there's a big question as to its use in control applications. A CtE editor pinpoints where it may fit based on what he heard at the Conference.

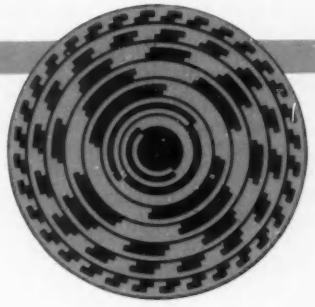
PHILADELPHIA—Probably the key characteristic of the solid state area is the rapidity with which the technology and emphasis can shift. Until two years ago the transistor and its circuit applications were at the focus. Last year the emphasis seemed to center on memory and logic devices for digital circuitry, particularly for digital computers—with most particular emphasis on high speed switching (see CtE, June '58, pp. 105-110). This year the Esaki tunnel diode has stolen the spotlight.

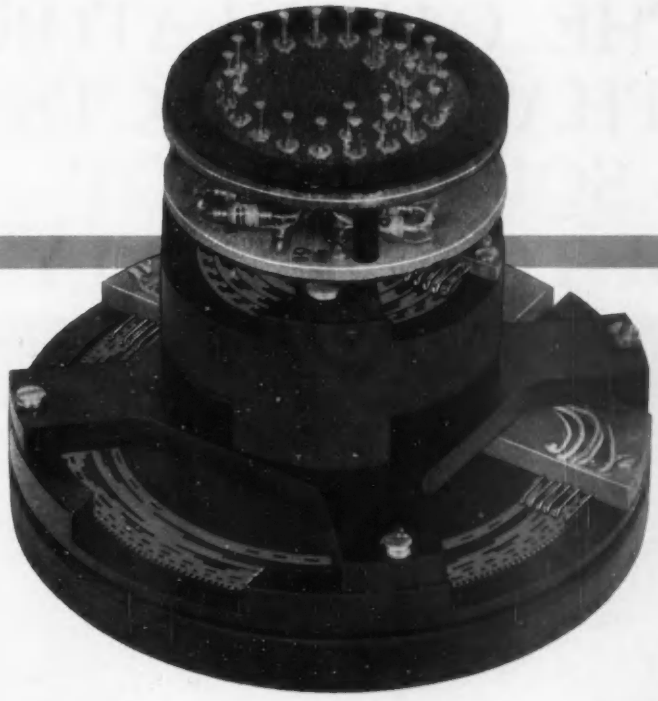
In Philadelphia last month the tunnel diode was a headliner at the rapidly growing Solid State Circuits Conference (this year's attendance: 3,100, a gain of 500 over last year). At the opening session the Esaki diode was the sole subject of discussion. Papers on the device were presented at four other sessions, too. And because of the unusual interest, the opening morning session was repeated in the afternoon so that those who had attended a concurrent session on thin films would also be able to hear the Esaki diode presentations.

To determine how this device might affect control, CtE studied the presentations and talked to many of those attending the conference. The conclusions:

- **The tunnel diode looks good for communications and data transmission amplifiers in ultrahigh frequency and microwave regions.**
- **It is not for low frequency amplifiers (but spectacular possibilities loom for modulation-based equipment like radio and telemetering).**
- **It has good possibilities for high speed digital logic circuitry.**
- **It will probably not be useful in computer memories.**

The tunnel diode is a low power device. That limits its application. Laboratory samples have operated at a few watts, but the average device runs





New Norden "disc" design creates

High count, multiple turn Gray encoders ...without indexing mechanisms

Norden engineers have succeeded in incorporating double brush logic in a Gray encoder, model ADC-16-GRAY, achieving multiple turn capabilities and high resolution per turn . . . without the need for between-stage indexing mechanisms.

Norden ADC-GRAY code units:

- meet or exceed military specifications.
- assure freedom from error due to positional ambiguities.
- are the smallest multi-turn Gray encoders available, and store nearly twice as much in a given diameter as units using a pure binary code.
- eliminate ambiguity situations caused by cross-coupling, simplifying telemetering problems such as may arise in space satellites.

Norden offers several models in Gray-code encoders with a total count range of 2^8 to 2^{16}. Review your requirements and send for detailed specifications and drawings or call TRinity 4-6721.

TYPICAL MODELS	TOTAL COUNT	REVOLUTIONS FOR FULL COUNT	DIAMETER
ADC-16-GRAY	65536	64	3.25
ADC-ST10-GRAY	1024	1	3.25
ADC-ST9-GRAY	512	1	2.25
ADC-ST8-GRAY	256	1	1.75

NORDEN

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Milford Department, Wiley Street, Milford, Connecticut

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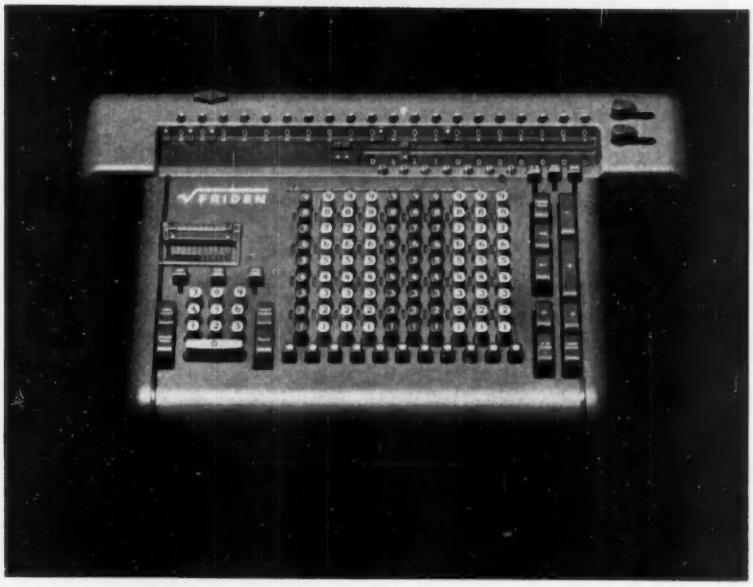
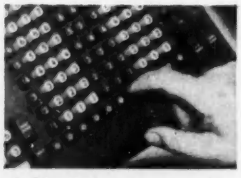


1. *On the keyboard, enter the figure from which the root is to be taken.*



2. *Touch the square root key corresponding to position of radicand's decimal point.*

3. *Automatically, the square root will appear in the dials. Time required: just seconds.*

Meet Friden's SRW—the Thinking Machine of American Business. It's a complete desk calculator in every way. *But it also extracts square root automatically at the touch of a single key. And it's the only calculator that can!*

If you now waste valuable productive time extracting square root by old-fashioned methods, put in an SRW and watch it pay for itself. Call your Friden Man or write to Friden, Inc., San Leandro, California.

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WHAT'S NEW

. . . with simple circuitry . . .

at a level of a few hundred microwatts.

Because of the absence of transit time effects, however, it is an extremely good high frequency amplifier that is certain to displace transistors above 100 Mc in low level signal applications. In addition, the tunnel diode requires much simpler circuitry than parametric amplifiers (which do have a lower noise figure). With straightforward microwave circuit techniques, tunnel diodes have been made to amplify at 10,000 Mc.

Below 100 Mc the tunnel diode will have to compete with transistors in amplifier applications on a purely economic basis. Because of the sharp nonlinearities of the negative resistance characteristic, one diode with simple circuitry can perform many functions such as oscillation, modulation, amplification, and detection—simultaneously. For such applications the tunnel diode may have no equal.

• **For high speed logic**—The reverse curve of negative resistance characteristics also produces another effect: the same forward current can exist for two different applied voltages. That means the tunnel diode can be made bistable through the proper choice of operating conditions. Such capability opens up a whole area of applications in digital logic circuitry. Moreover, since the tunnel diode can be made to switch as fast as 1 millimicrosec, the logical systems can be exceedingly fast.

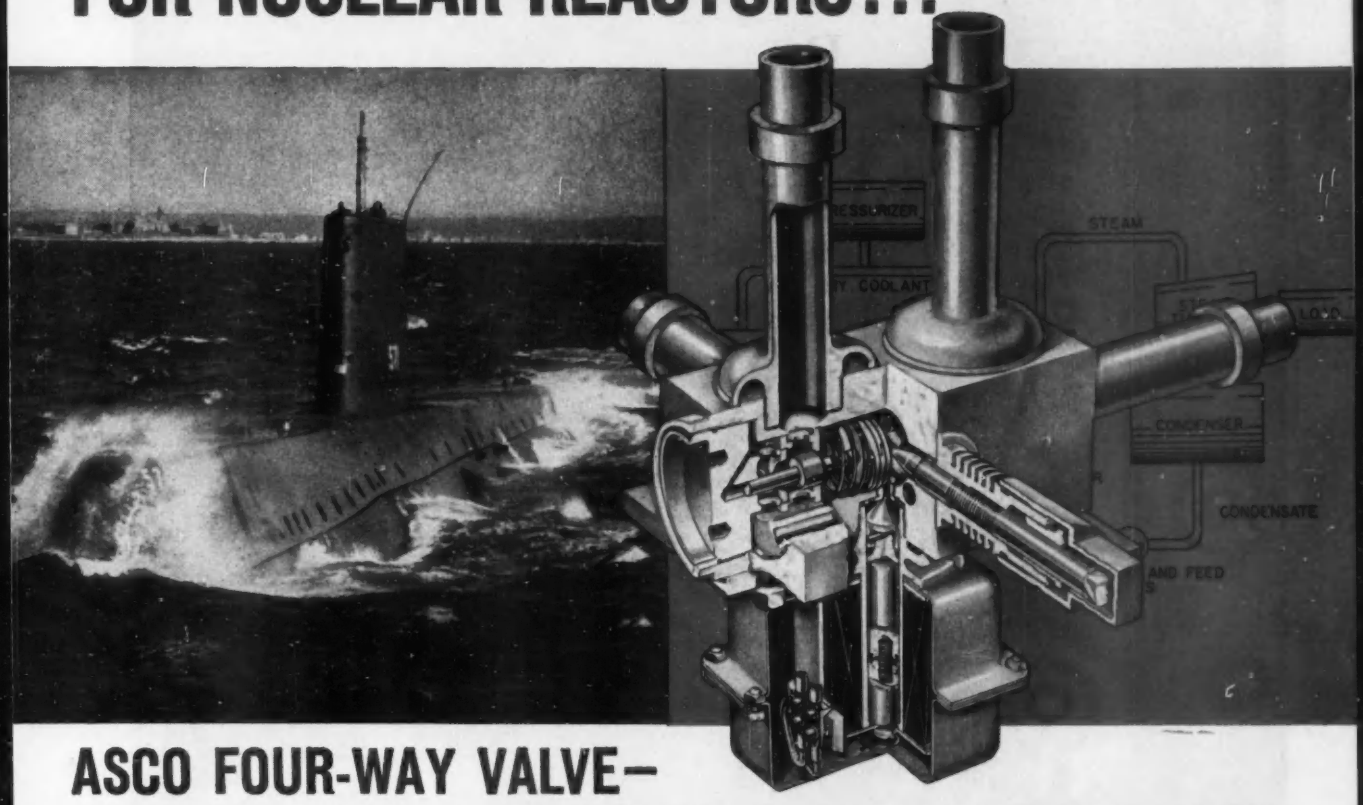
Where many circuits must be cascaded to produce effective results, a circuit design problem arises. Because the tunnel diode is a bilateral device, there is no isolation between input and output. In fact, for very small or very large currents, it is not a diode at all since it passes current with equal ease in either direction. As a result, circuitry becomes complex. Some of the circuits described for digital logic have had to employ three-phase synchronized clock-pulse type of power supplies like those used in some parametric amplifier schemes.

• **In computer memories**—Will the tunnel diode ever be used for bit storage in the high speed memory section of computers? Not likely, even with its high switching speed. For one thing, thin film memories should approach these speeds (within an order of magnitude) at considerably less cost per bit in large memories. Use of the full capabilities of the tunnel diode in memories would require microwave techniques at much higher expense.

—E. J. Kompass

CIRCLE 39 ON READER SERVICE CARD

SOLENOID VALVES FOR NUCLEAR REACTORS...



ASCO FOUR-WAY VALVE— CONTROLS ISOLATING VALVE IN CIRCULATING LOOP

From ASCO's nuclear energy facilities — the only ones in the Solenoid Valve industry to include a *hot test loop* — now comes a complete family of solenoid valves tailored to atomic energy requirements.

Typical is the 4-way valve illustrated above designed for the control of the main cylinder-operated isolating (stop) valve in the circulating loop. This stainless steel, packless type (hermetically sealed) valve features exceptionally tight seating—through beveled, poppet-type seats and discs. Solenoid pilot controlled and available with manual override, it is supplied in 1" size. This unit is suitable for 2500 P.S.I. differential pressure at 600°F.

Like all other ASCO Solenoid Valves designed for nuclear reactor systems, this valve has passed the most rigid tests under faithfully duplicated working conditions. ASCO 4-way Solenoid Valves are now in use on nuclear submarines powered with water-cooled reactors. Uniformly reliable and maintenance-free, ASCO 2, 3 and 4-way Valves are specified for primary and secondary systems of nuclear reactors, as well as for instrumentation control.

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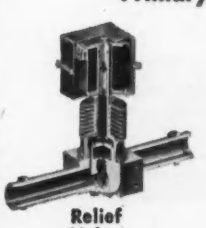
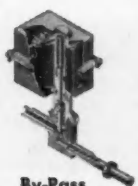
Primary System



Relief Valve



By-Pass Coolant Valve

Secondary System

2-way Valves

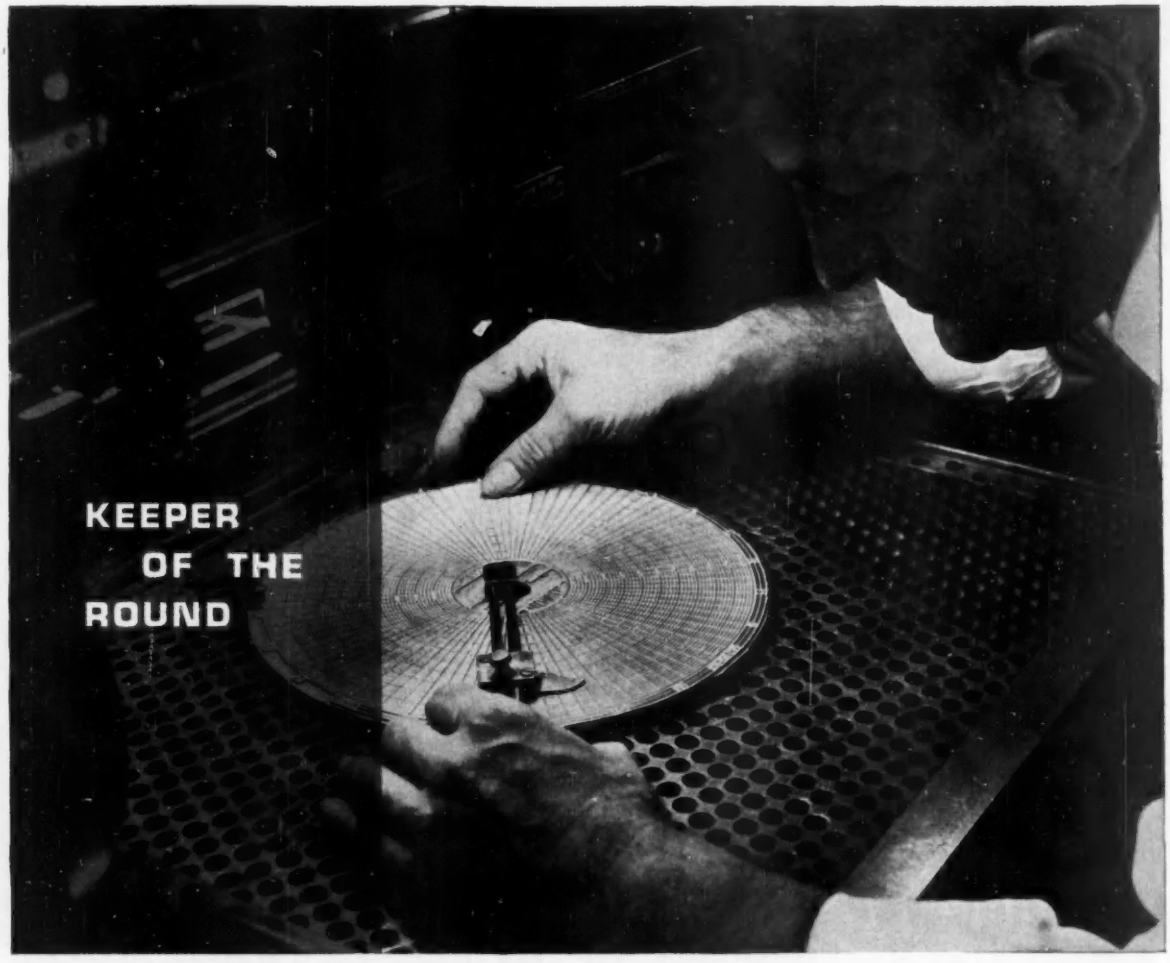
3-way Valves

Instrumentation Control

2-way Valves

3-way Valves

CIRCLE 41 ON READER SERVICE CARD



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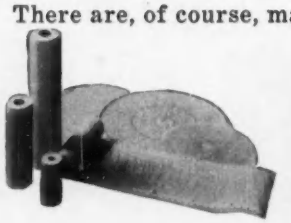

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CIRCLE 41 ON READER SERVICE CARD

EUROPEAN REPORT

Holland Builds Europe's Most Mechanized Air Traffic Control Center

Computer control of air traffic is planned for Amsterdam's Schipol airport. Operation of Phase I equipment will start this summer.

At Amsterdam's Schipol airport, workmen are installing equipment for the Low Countries' first mechanized air traffic control system. Designed to simplify the clearance and tracking of jet airliners, to reduce the workload of air traffic controllers, and to assure maximum safety in Holland's well trafficked air, the SATCO system is being built in two phases.

▶ Phase I, with automatic flight strip printing, should be operational this summer.

▶ Phase II, which will have fully automatic displays, conflict prediction, flight path calculation, and automatic coordination between controllers, should be delivered by October 1961.

Design of SATCO, built by N. V. Hollandse Signaalapparatens (a subsidiary of Dutch Philips) has been influenced by the peculiar air traffic control requirements of Europe. The most severe: the complete autonomy of adjacent countries demands compatibility with nonmechanized centers, low traffic densities, and fewer terminal points. And SATCO is modular so it can grow with traffic.

Most important component in the system is a transistorized digital computer which uses standard teleprinter code input and output. Clock rates are switchable from a normal 300 kcps down to 1 cps, a speed for checking. A single 70-track magnetic drum can store 250,000 bits of flight data; a 30,000-bit core memory stores track, distance, runway coordinates, aircraft type, and other constants.

In Phase I equipment basic data is extracted manually from the pilot's flight plan and punched into the computer by teleprinter. Data fed to the computer store includes aircraft call sign and type, takeoff and destination points, reporting positions along route, and pilot's preferred flight level and speed. Scheduled flights are prepunched on teleprinter tape; takeoff time and altitudes are entered later.

After an "execute" command from the teleprinter, the computer examines the identification letters of the takeoff and destination points to determine whether the aircraft is inbound, outbound or overflying; then the computer chooses the appropriate program.

• **From takeoff**—On an outbound trip, the computer prints out on modified teleprinters two identical flight strips at the outbound controller position and the data entry clerks' position —within 1 sec of data entry. The controller determines clearance altitudes and type of clearance—the clearance can be any combination of 10 conditions—and passes them along to the pilot and to the data entry clerk who punches the additional data into the computer. This is stored along with the previous data in the computer. Any takeoff delays, of course, obviate calculations on the check point arrival times which are based on the estimated departure time.

After the controller enters the actual departure time in the computer, it computes arrival times and altitudes at each reporting point. Based on the tvpe of clearance instructions issued, the computer determines the climbing path and levelling off point in time and distance from airport.

Wind directions—divided into four territorial areas and 10 vertical layers—are fed in from the meteorological office. Vector calculations based on the aircraft speed and characteristics—these are preprogrammed under 10 different basic aircraft categories—use the wind information to correct speeds and arrival times.

Dividing the aircraft flight direction into either east- or westbound selects the printout teleprinter, one producing yellow flight strips for eastbound, the other blue for west. A separate strip is automatically produced for each reporting position, and they are stacked in front of the controller. A yellow-blue combination indicates a possible head-on collision.

• **Abolishing paper strips**—Biggest advance in air traffic control, however, will come with the Phase II Schipol installation. When this equipment is installed, printed flight strips will be eliminated by automatic displays. Automatic conflict presentation and automatic data transfer between controllers' sectors will also be performed.

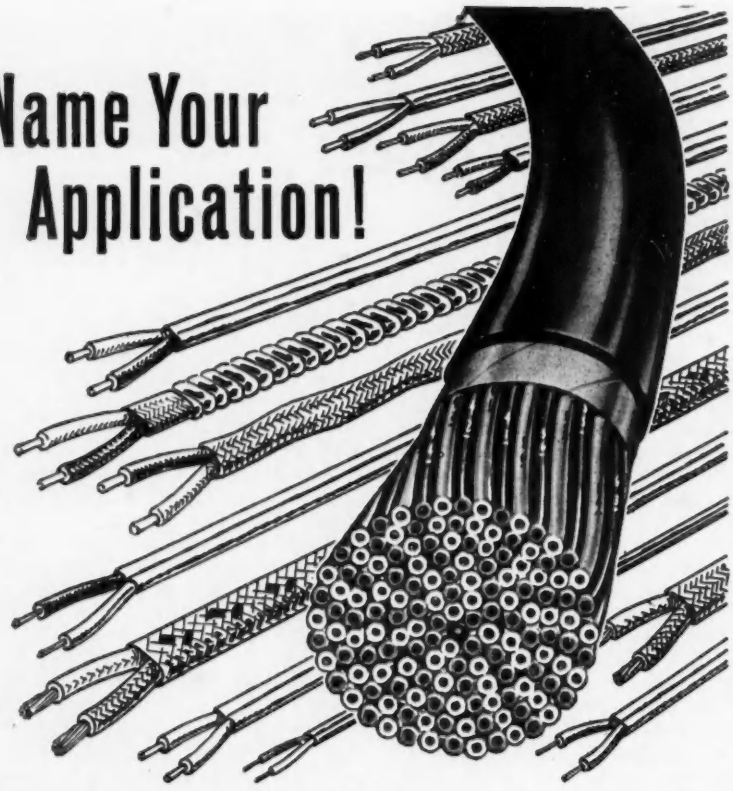
Each of Schipol's three ATC sectors will have an autocontrol board, similar to the conventional flight strip bays. Each board will have four panels, each panel comprising 24 flight strip assemblies. These assemblies replace the paper strips, contain 30 indicators together with aircraft approach, conflict, and check lamps.

Output information is supplied by electromechanical indicators with both read-in and read-out characteristics. Maximum rate of character presentation is around 60 per sec. An endless band carrying 40 characters is driven by a high speed stepping switch. Brushes and notches on the endless band control which character is indicated in the display window. By providing a temporary memory storage for aircraft flight data, this technique frees some computer storage. In case of a failure, all indicators are frozen in the last position.

Another innovation on the automatic flight strip is a splitting of the information. Only essential facts appear on the strip; other data on the flight can be instantly called up from the computer by pushbuttons on the controller's desk. Strip information appears in two colors: red for actual or cleared heights and times, black for predicted data.

The controller sees the aircraft's call sign, last reported flight level, reporting point just passed, cleared flight level, ground speed, destination, pilot's estimated time of arrival, plus eight symbols. The last indicates whether the plane is under radar control, east-

Name Your Application!



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WHAT'S NEW

. . . to coordinate information the computers is tied to indicators in each sector . . .

or westbound, and flight attitude (level, climbing, or descending). A special type-face developed at Cambridge University should minimize visual reading errors on the indicators.

The controller can request 17 extra information items. These include call sign (as a visual check that the controller has selected the correct flight number), aircraft type, planned flight level, descent and levelling off points and times, place of departure, route, destination, indicated air speed, VOR references, and estimated arrival time.

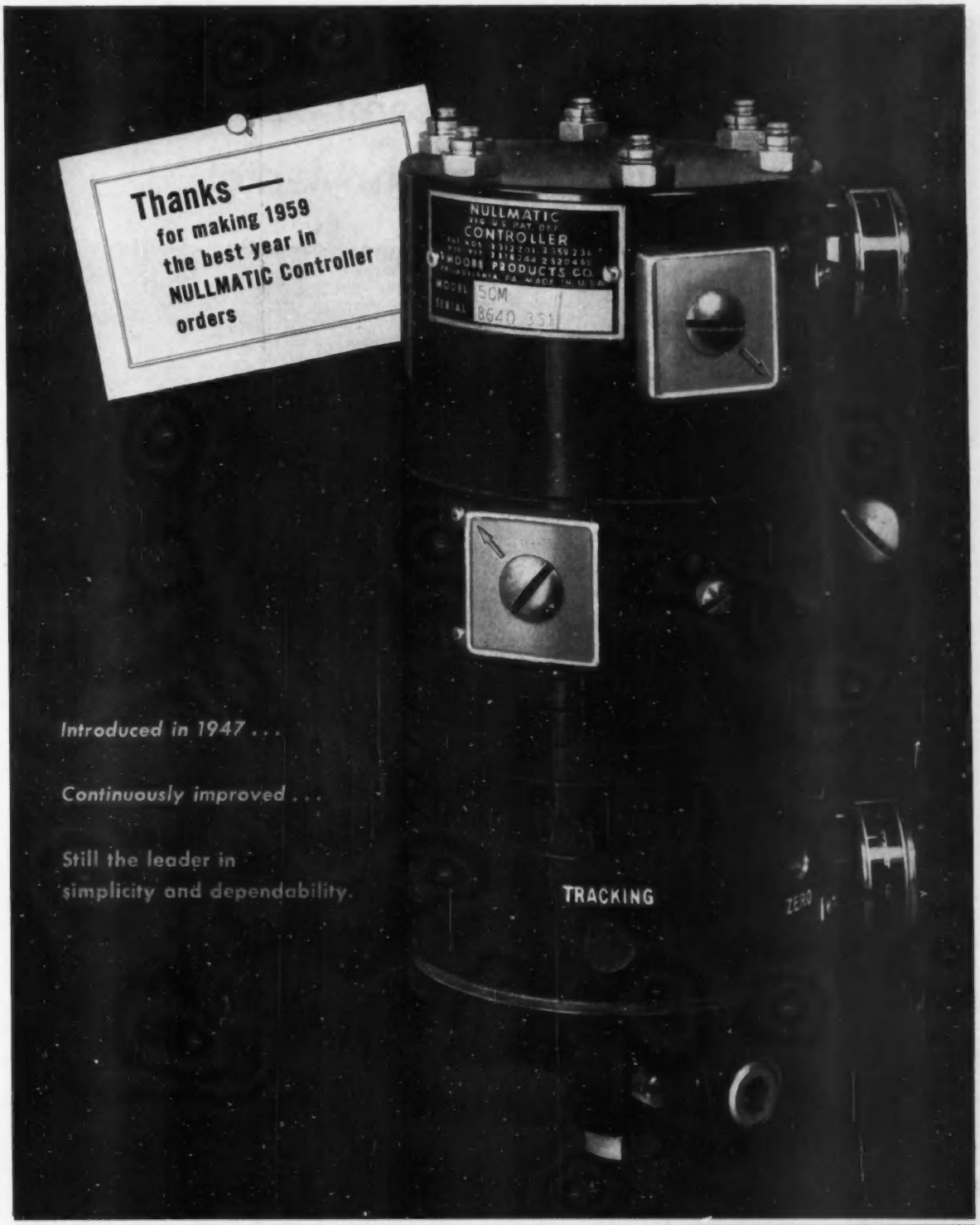
To coordinate information supplied to each sector controller, SATCO interconnects the indicators from the computer. When flight strips are prepared in the machine, identical information of the transfer points appears on every sector board, eliminating the bogey of transcription errors which can appear if flight strips are prepared manually.

To give the controller a quick check on aircraft coming into his sector, white lamps light continuously against flight strips belonging to approaching aircraft. When aircraft are about to enter the sector, this changes to intermittent flashing. On receiving the actual entry time from the pilot, the controller enters this time into the computer which then recalculates all forward arrival times and extinguishes the arrival lamps.

Information changes on the flight plan can be fed into the computer directly by pushbutton at the controller's console. Unchanged information on the flight strip is read directly from the built-in brush and notch memory system of the indicators themselves. Whenever any flight path information is changed, the computer conducts a conflict search looking for:

- Aircraft at each reporting center located at the same height and arriving within 10 min of the newly positioned aircraft.
- Any other aircraft between the reporting centers crossing the flight line of the aircraft that is being controlled.

By far the trickiest calculation is the second, involving checking all other aircraft routes to see if they cross the controlled aircraft's line of flight. If so, a second computation stage checks the individual aircraft heights during this time interval to check the interception. —Derek Barlow



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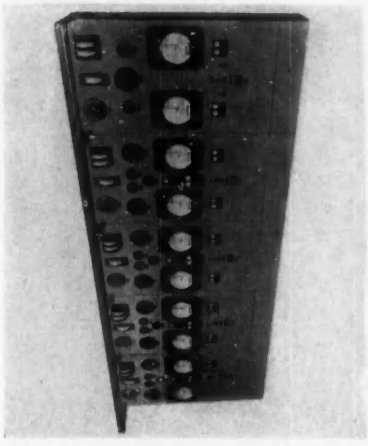

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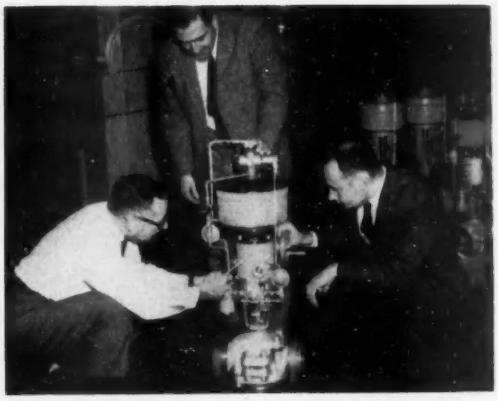
One Company Solves the European Market



Headed for a European customer, this control valve gets a preshipment admiring survey from the Conoflow men concerned with marketing in Europe: Executive Vice-President John C. Koch (at left), Sales Manager J. R. Simpson (center), and Director of European Sales Melvin Fusfeld (right).

Conoflow, a control valve manufacturer, has parlayed a half a dozen inquiries per year into a profitable export business.

PHILADELPHIA—Inquiries from Europe used to come into the Philadelphia plant of Conoflow Corp., manufacturer of final control elements, at a rate of about half a dozen a year. When Conoflow application engineers answered them, they expected little in the way of results. Sometimes weeks of correspondence would pass, and the company even got a few mail order sales this year.

The company had never seriously considered the European market because Conoflow executives anticipated problems of language barrier, low volume, differences in standards of measurements and other roadblocks that might consume more time and energy than returns would ever warrant.

But since 1958 the market situation in Europe has changed so that any company has had to take a second look at selling in Europe. Sparked by the formation of the "inner six" (the European Common Market) and the "outer seven" (Free Trade Area) groupings of countries to facilitate trade, Europe is no longer many small individual markets. Now Europe is two giant lucrative markets with populations of 100,000,000 and 160,000,000—big enough to encourage the construction of large scale plants to serve this market. And the construction of such plants means a ready market for measurement and control equipment.

Conoflow Executive Vice-President John Koch was in the midst of taking his second look at this burgeoning new market when a business associate introduced him to Melvin Fusfeld, an instrument engineer with a new idea of how to do business in Europe. On a trip abroad, Fusfeld had seen this booming market start to materialize, but even more important, he had noticed that most U.S. companies treated European customers as poor relations. Foreign inquiries were handled either at low priority or by an export department in which the company had put its lesser lights, saving the stars for more lucrative domestic sales. Fusfeld's idea was disarmingly simple: *treat the European market as if it were just another sales territory.*

• **Super representative**—Actually Fusfeld's proposed operation was more complicated than the idea. He proposed that he move to Europe and serve as a kind of "super manufacturer's representative". He would line up existing organizations in Europe with the engineering know-how to apply Conoflow's final control, with the sales organization and talent to sell the equipment, and the financial stability to relieve fears about payment and credit. In return Conoflow would handle his operation just as if it were part of the United States; all inquiries were to be processed the

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Rotovalve unit for 2700-psi, 1050 F service.

A must for nuclear reactor service . . . valves that

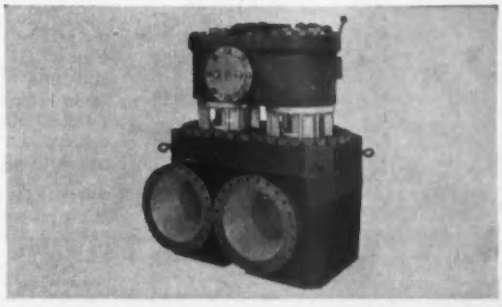
seat tighter with use

***Rotovalve* units accurately control or shut off** in high-temperature, high-pressure reactor applications. Units feature lantern ring with double packing, pressurized with the line fluid or purged to a bleed tank at lantern ring.

One example of current manufacturing is a 10-inch *Rotovalve* unit for operation at 2500 psi, 2500 F. Also being engineered is a 12-inch size for service at 4000 psi, 4000 F. Still another type combines a pair of valves within a single housing for use on dual, concentric pipes. Inner pipe carries 1400 F CO_2 to reactor; outer, 700 F CO_2 away from reactor.

Your Allis-Chalmers representative can arrange reactor valving engineered to your specific requirements. He also supplies a complete line of butterfly valves, including models for air-lock valving. *Contact him for detailed information, or write* ***Allis-Chalmers,*** *Milwaukee 1, Wisconsin.*

Rotovalve is an Allis-Chalmers trademark.



Duplex Rotovalve unit features a single operator — controls 1200-psi, 600 F steam, or 1500-psi, 300 F air. Operator allows both valves to open simultaneously, or one to open while the other closes. Saves space vital where entire reactor unit must be enclosed in radiation-proof structure.

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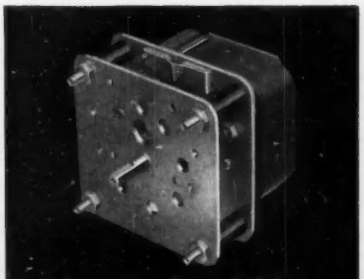
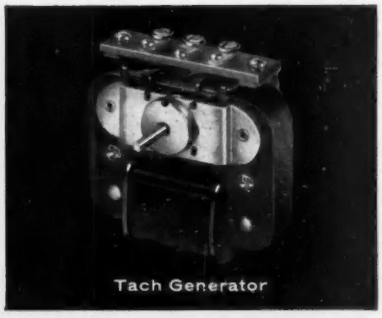
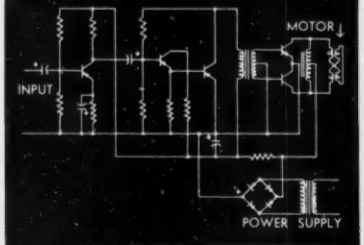
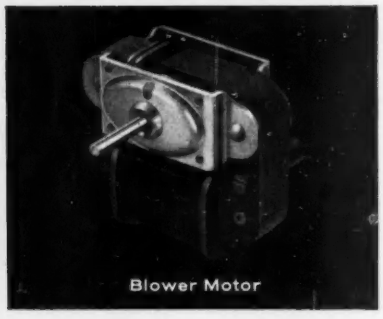

Reversible Geared Motor


Tach Generator

TYPICAL CONTROL CIRCUIT

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QUALITY GUARANTEED

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WHAT'S NEW

same way whether they come from Wilmington, Del., or Gotenburg, Sweden.

• **Big payoff**—Final test of Fusfeld's approach was to be in sales. Today, Koch is the first to give this way of handling export sales a top grade. In 1959, only the second full year the approach was tried, Conoflow's annual export sales rose from practically nothing to 10 percent of the company's total sales. This year, John Koch expects that export sales will almost double.

Conoflow Sales Manager J. R. Simpson has been more impressed by one other benefit of the new approach. It has led to a lot of bread and butter business, orders that run only $3,000 or $4,000 apiece, but which come in steadily. Such business has helped level off the peaks and dips in U.S. business, he points out.

• **New look at selling Europe**—Fusfeld credits this success to the radical change in selling and buying habits that is hitting Europe. For the first time, European representatives are running into the same technical problems as their counterparts in the U.S.; they are being asked to engineer similar applications because of the boom in capital spending for new plants.

In a lot of ways, doing business in Europe is easier these days for U.S. companies. Shipboard container services have obviated the special and expensive export packings which used to be required, as just one example.

And there's been a revolution in communications. The jet commercial airliner has made traveling from Philadelphia to Paris barely more difficult than it used to be to fly from the Quaker City to Los Angeles. European Sales Director Fusfeld, who operates out of The Hague in Holland, can visit a potential customer with a European distributor on Monday, have an inquiry in the mail Monday afternoon bound for Philadelphia. It arrives at Conoflow on Wednesday where an application engineer can review it and send an answering quotation in the mail Wednesday. By Friday afternoon, the European agent is ready to face his customer with a quotation. The European transaction can sometimes be completed faster than a similar one that takes place with a Los Angeles agent.

One thing that makes the communication business easier is the broadening use of English by technical men in Europe.

• **Will it work for everybody?**—Is Fusfeld's approach the answer for all

small manufacturers? Definitely not, he emphatically says. For one thing, he warns, U. S. control suppliers normally go into the European market with a price disadvantage. U. S. standard valves, for example, cost 20 to 40 percent more than similar European-made valves because of Europe's cheaper labor. To compete under such circumstances, a company must be able to offer a product whose design is unique, with features not available from European manufacturers.

Another key requirement is exceptional distributors. The organizations which Fusfeld has signed up have to be more selfsufficient than those Conoflow users in the United States. For one thing these distributors must perform the bulk of the application engineering. For another, they carry out all servicing and maintenance.

Although Conoflow normally ships direct to the user in the United States, it frequently doesn't know who the European customer is. All export shipments go to the distributor who ordered the shipment.

Breaking into European trade sometimes takes a new slant or an attack on a new market. For example, Conoflow has done little selling to the U. S. shipbuilding industry which is unique and difficult to crack. Because European shipbuilders form a major segment of continental industry, Conoflow decided to make a try. Through its Netherlands distributor, which had a background of selling other equipment to shipbuilders, it has opened the door by selling several valve installations on tankers. Conoflow is are aiming at passenger liners.

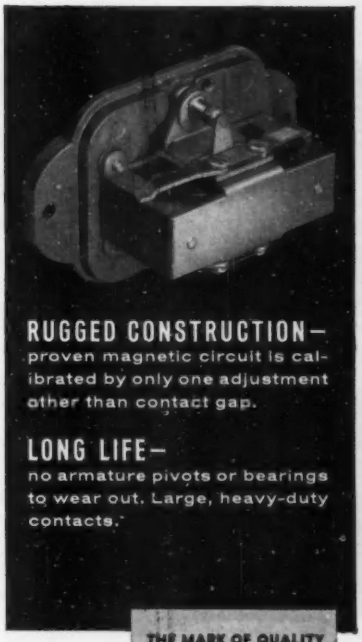
This switch has some interesting implications. Fusfeld has brought back to Conoflow know-how and experience in shipbuilding with which the company expects to be able to compete for U. S. ship valve business.

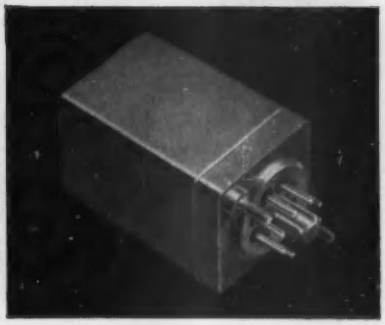
• **A temporary salve**—Although Conoflow sees their export business with Fusfeld booming, there is a limit to what the company can expect. Probably the most severe pressure will come from plants built in Europe by U. S. competitors. Still several years away, such a competitive situation almost forces a company to build in Europe if it wants to continue to enlarge its share of the market.

Meanwhile, Conoflow is happily watching new business come in, orders like the one for valves for the biggest copper refinery in the world which was built by Union Miniere du Haut Katanga in the Belgian Congo. Two years ago, sales manager Simpson says, Conoflow would never have gotten that order. When an inquiry for this job arrived from Belgium, it re-

(Continued on page 198)

Practical solutions to many of today's complex control problems . . . ultra-sensitive d-c polarized relays by Barber-Colman . . .





RUGGED CONSTRUCTION— proven magnetic circuit is calibrated by only one adjustment other than contact gap.

LONG LIFE— no armature pivots or bearings to wear out. Large, heavy-duty contacts.

THE MARK OF QUALITY

BARBER COLMAN

OFTEN SIMPLIFY ELECTRONIC AMPLIFIERS...REPLACE SEVERAL TUBES

VOLTAGE OR CURRENT SENSITIVE

RAPID RESPONSE

SMALL PULL-IN, DROP-OUT DIFFERENTIAL

ANTI-BOUNCE CONTACTS OPTIONAL

Barber-Colman Micropositioner d-c polarized relays are capable of operating on input power as low as 40 microwatts. Ideal for many aircraft and industrial control problems.

POLARIZED RELAYS — Available in three types of adjustment: null seeking . . . magnetic latching "memory" . . . and form C break-make transfer.

ALSO TRANSISTORIZED TYPES of above relays with built-in preamplifier to greatly reduce input power needed to operate contacts.

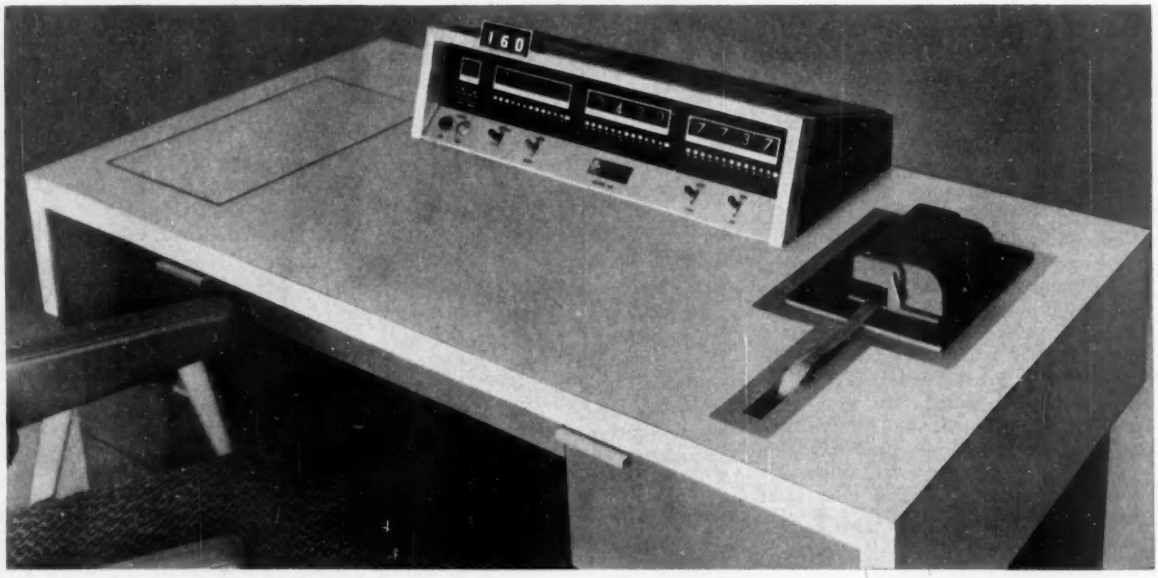
WRITE FOR NEW QUICK REFERENCE FILE on the complete line of Barber-Colman electrical components. Includes detailed specifications on a-c and d-c motors, tach generators, blowers, gearheads, relays.

BARBER-COLMAN COMPANY
Dept. D, 1848 Rock Street, Rockford, Illinois

Announcing the most versatile solid state computer in the low price field

Small as an ordinary desk, the Control Data 160 has the capability of computers many times its size.

IN THE 3 SECONDS IT TAKES YOU TO READ THIS SENTENCE . . . THE NEW CONTROL DATA 160 EXECUTES 180,000 INSTRUCTIONS



QUICK FACTS FOR MANAGEMENT

VERSATILE: Offers broad use in fields of engineering and scientific calculation, real-time data processing, data conversion, data logging and data acquisition, industrial control, communications systems, statistical and business data processing.

FAST: You can execute 60,000 instructions per second. The 160 uses solid state circuits and a *magnetic core memory* like those used in the Control Data 1604 — one of the newest, most advanced large-scale computers made today.

POWERFUL: The desk-size 160 gives you performance better than that of many large-scale computers in use today.

EASY TO USE: Experienced programmers can learn the 160 in one day. A two-week course is available for inexperienced personnel.

AND LOW IN COST! $60,000 for the basic system.

QUICK FACTS FOR THE TECHNICAL STAFF

1. MAGNETIC CORE STORAGE: 49,152 bits. Storage cycle time, 6.4 microseconds. Basic add time, 12.8 microseconds. Information read available 2.2 microseconds after start of cycle. Average execution time, 15 microseconds per instruction. 5 megacycle logic. Will handle input-output speeds of up to 65KC.

2. OPERATING MODE: Operation controlled by an internally stored program. Single address logic, one instruction per word.

3. PROGRAMMING: Repertoire of 62 instructions. Ease of programming features flexible addressing modes — no address, direct address, indirect address and relative address. Complete programming package includes 22-, 33-, 44-bit fixed point arithmetic, floating point, complex floating point, decimal, floating decimal, and algebraic compiler.

4. INPUT-OUTPUT: Versatile instructions provided to handle available line of input-output devices: 350 character/second paper tape reader, 60 character/second paper tape punch, electric typewriter, up to 8 magnetic tape handlers (either 15KC or 30KC), card reader, card punch, and line printer.

CONTROL DATA CORPORATION

501 PARK AVENUE • MPLS. 15, MINN. • FEderal 9-0411

Sweep Oscillator System

with Plenty of Frequency Coverage

By merely substituting basic oscillator units in this system, you can cover, in narrow or wide sweeps, segments of the frequency range from 500 kc to 2000 Mc. More than this, you can control sweep speed, center frequency and frequency span over wide ranges by simple knob adjustments.

The Type 1263-A Regulated Power Supply is designed to power the Unit Oscillator as well as to keep the oscillator's output constant over wide ranges of frequency. It does this by comparing the rectified r-f output of the oscillator against an internal reference voltage, and applying any necessary corrections to the oscillator through its plate voltage supply. With this setup output is maintained within 2% over the oscillator's entire frequency range.

Write For Complete Information

★ Sweep Drive's claw-like arm attaches to knobs and dials up to 4 inches in diameter, and to ¼- and ⅜-inch shafts to convert oscillators, signal generators, and receivers to sweep operation.

★ Sweep-speed, sweep-arc, and sweep-center frequency are completely adjustable even while the Drive is in motion.

★ Wide range of sweep speeds . . . reciprocating motion, adjustable from 0.5 to 5 cps.

★ Sweep arc adjustable from 30° to 300°. At sweep speeds below 1 cps, arc can be increased by coupling Drive directly to Oscillator dial rather than to control Knob attached to vernier reduction-drive.

★ Rated maximum torque is 24 ounce-inches. Limit-switch circuit disconnects and brakes motor should limits of shaft travel be accidentally exceeded.

★ Generates a horizontal deflection voltage proportional to shaft angle for scope displays and x-y recorders.

★ Blanking circuit shorts out CRO trace during return portion of cycle and produces a reference base line.

GENERAL RADIO COMPANY

WEST CONCORD, MASSACHUSETTS

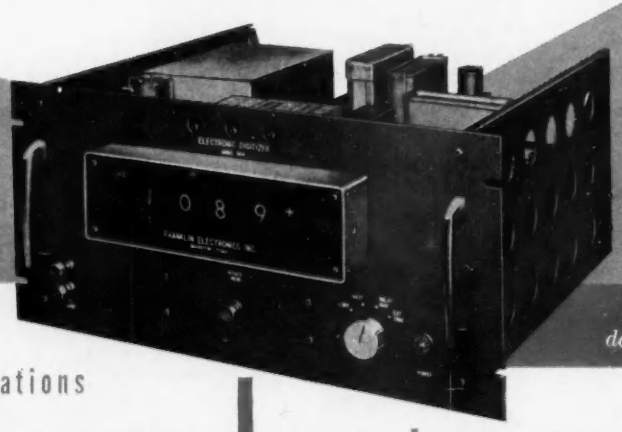
NEW YORK, WOrth 4-2722	CHICAGO	PHILADELPHIA	WASHINGTON, D.C.	SAN FRANCISCO	LOS ANGELES	IN CANADA
District Office in Ridgefield, N. J. WHitney 3-3140	Oak Park Village 8-9400	Abington HAncock 4-7419	Silver Spring JUniper 5-1088	Los Altos WHitecliff 8-8233	Los Angeles HOllywood 9-6201	Toronto CHerry 6-2171

CIRCLE 51 ON READER SERVICE CARD

long-term stability...ONE YEAR

MODEL 1310N A-to-D CONVERTER/VOLTMETER

There's never any need for exasperating knob twiddling with a Franklin Model 1310N. Magic? No, just plain practical design. All operating potentials, including the line voltage, are regulated before they're put to work. What's more, there are no stepping switches, relays or other mechanical components to introduce noise or delays . . . it's all-electronic for whisper-smooth voltage conversion . . . and with a stability never before equalled. The brief specs tell more.



MODEL 1310N, ALL ELECTRONIC ANALOG-TO-DIGITAL CONVERTER/VOLTMETER..... $2090*

request data sheet 2006

brief specifications

RANGES:	000.0 to 120.0 V dc. Input sensitivity: 0.1 V per digit. Matching amplifiers are available with minimum ranges of 1 mv per digit or 100 uv per digit.
RANGE AND POLARITY SWITCHING:	Optional automatic or manual (with amplifier).
ACCURACY (ABSOLUTE):	± one count (± 0.1% of full scale) after 10-minute warmup.
STABILITY:	Absolute accuracy is maintained for at least one year without calibration.

INPUT IMPEDANCE:	100 megohms.
READOUT TIME:	Maximum of 12.2 milliseconds to 120.0 volts full scale.
SPEED:	Up to 40 readings per second.
POWER:	100—125 V, 60 cps, 200 watts.
DIMENSIONS:	19" rack panel unit, 8¾" H x 15" D.
WEIGHT:	Approximately 50 pounds.

*Prices are F.O.B. BRIDGEPORT, PENNSYLVANIA.

FRANKLIN electronics, inc.

BRIDGEPORT PENNSYLVANIA

VAN NUYS CALIFORNIA

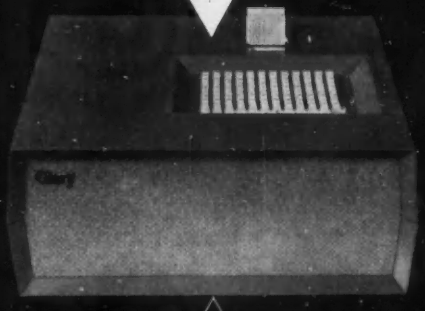
You count best when you count on FRANKLIN

NEW CLARY SCANNING PRINTER ACCEPTS

BOTH DECIMAL AND CODED DATA...

ON SAME LINE...AT NO EXTRA COST...

from digital voltmeters, shaft position transducers, electronic counters, EPUT meters, step switch banks, relay banks, selector switches, digital clocks ...draws negligible power from these sources...



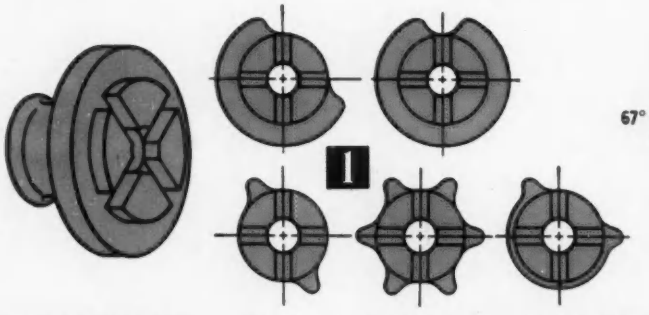
...and color-prints in black and red at three lines per second, with a capacity of 12 digits per line. Full manual keyboard is standard. For more information on the Clary Model 1961 Scanning Printer, write today for Engineering Bulletin No. S-111.

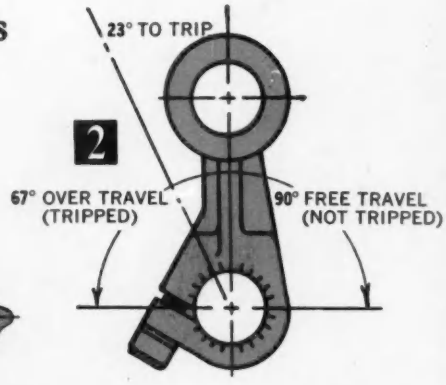
Clary ELECTRONICS DIVISION
CLARY CORPORATION
San Gabriel, California

The SL2 snap-lock • Newest NAMCO Machine Life Limit Switch

Snap-Lock Limit Switches, developed by National Acme to meet rigid specifications, have become industry's standard for reliable "machine life" service. Latest and most advanced in the complete line is the SL2. Built with machine tool precision and ruggedness, it will give millions of fast, accurate contacts. Furthermore, it is water and oiltight and can stand the bruising conditions imposed by heavy-duty machine applications. You owe it to yourself to closely examine the *combination* of performance characteristics that assure completely reliable limit switch performance under the most extreme operating conditions.

Closely Check These Outstanding Features





1. Flexible Operation . . . To meet the requirements of any application, standard cam blank (above, left) can be cut into a wide variety of configurations including those shown. Interchangeable, these cams provide positive control of contact sequence; permit tailoring switch performance to individual jobs.

2. Ample Overtravel and By-pass . . . Sixty-seven degree overtravel . . . 90° by-pass . . . 180° arc.

3. Clockwise or counterclockwise motion . . . Converting from clockwise to counterclockwise motion takes but a few seconds.

4. Light Operating Pressure . . . Tripping action requires only 12½ pounds at 1½ inch radius . . . 50% less than previous models. Overtravel reduced so as to require only 8 pounds at 1½ inch radius.

5. Shock-proof Design . . . Positive mechanical lock mechanism withstands shock and vibration.

6. Fast Contact Action . . . High make-and-break contact speed permits use in unusual applications.

7. High Contact Pressure . . . Contact bounce minimized by use of new contact material that permits 15 oz. contact pressure.

Write for Bulletin EM-SL60 containing complete detailed information

National Acme

The National Acme Company
165 E. 131st Street
Cleveland 8, Ohio

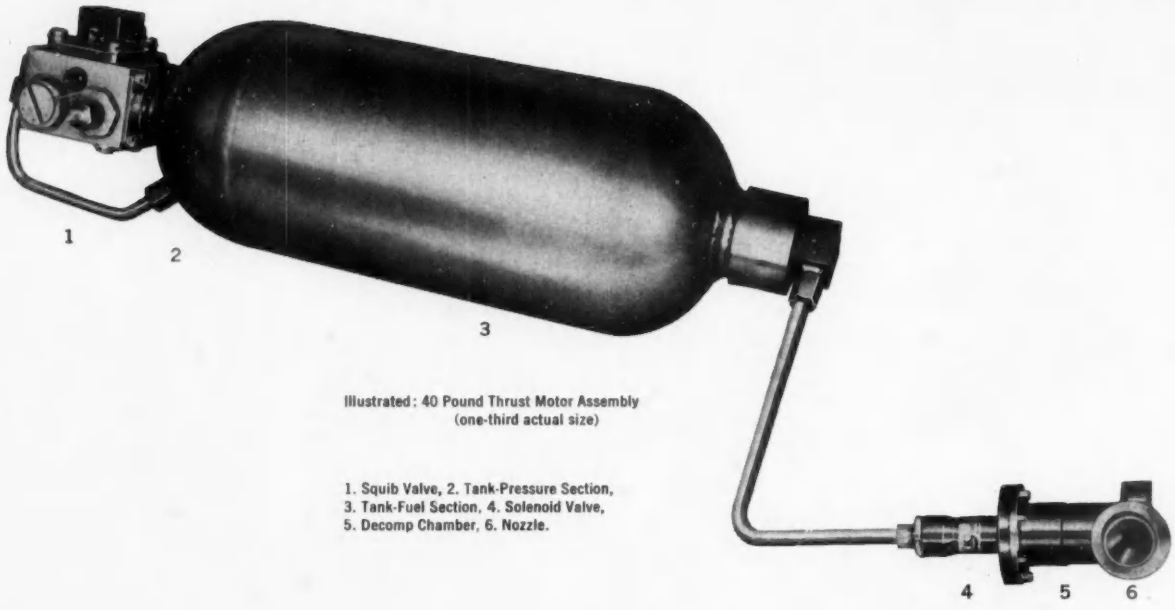
Sales Offices: Newark 2, N.J.; Chicago 6, Ill.; Detroit 27, Mich.

CIRCLE 54 ON READER SERVICE CARD

NAMCO
SNAP-LOCK
SWITCH
SL2
VOLTS AC DC
AMPERE RATING
125 20 5.0
250 15 1.5
480 10
600 5.0
THE NATIONAL ACME CO
CLEVELAND, OHIO
MADE IN U.S.A.
PAT. PENDING
NAMCO
SL2

Sales Offices: Newark 2, N.J.; Chicago 6, Ill.; Detroit 27, Mich.

CIRCLE 54 ON READER SERVICE CARD



Illustrated: 40 Pound Thrust Motor Assembly
(one-third actual size)

1. Squib Valve, 2. Tank-Pressure Section,
3. Tank-Fuel Section, 4. Solenoid Valve,
5. Decomp Chamber, 6. Nozzle.

REACTION CONTROL SYSTEMS BY KIDDE are highly reliable, now in production. Today being used on the NASA Scout, Air Force Thor, and the Air Force HETS, they are low in cost, light in weight, highest in performance. Kidde systems use mono-propellant, bi-propellant, cold gas, or solid fuels. Thrust motors from 2 to 600 pounds. For repeatability, response, and reliability in reaction control equipment, Kidde can serve you best! Write to Kidde today outlining your reaction control requirements.

K Kidde

Kidde Aero-Space Division

Walter Kidde & Company, Inc., 417 Main St., Belleville 9, New Jersey

Walter Kidde-Pacific, Van Nuys, California • Walter Kidde & Company of Canada Ltd., Montreal, Toronto, Vancouver

District Sales Engineering Offices: Dallas, Texas • Dayton, Ohio • St. Louis, Mo. • San Diego, Calif • Seattle, Wash. • Van Nuys, Calif. • Washington, D. C.

Foxboro pH Dynalog Recorder has an input impedance of 80,000 megohms — eliminates the need for intermediate amplification. Span is adjustable from 2-12 pH; zero, from 0-12 pH.

Foxboro eliminates the amplifier from pH recording and control

cuts the drift, cuts the cost, cuts the maintenance, too!

Foxboro pH Dynalog Controller — for use where it is desired to hold pH at a predetermined valve.

Foxboro pH Dynalog Indicator — for use where complete record of pH value is not required.

THAT'S RIGHT — the intermediate amplifier is gone from Foxboro's new low-cost system for measuring pH. And gone with it is the wasted panel space, the drift, the daily standardization inherent with earlier systems.

In the new Foxboro system, the signal from the pH electrode goes direct to a high impedance Dynalog* receiver — without intermediate amplification. Signal operates a direct-reading indicator or recorder—or a controller and alarms, when desired.

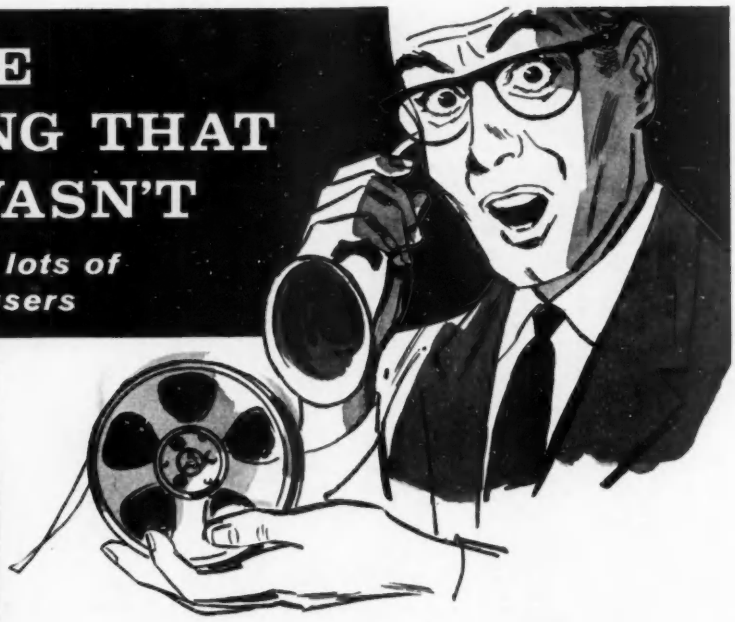
The new Foxboro pH system is the simplest, most economical method of measuring pH available today. Ask your Foxboro Field Engineer to tell you about it. Or write for data sheet. The Foxboro Company, 854 Neponset Avenue, Foxboro, Massachusetts.

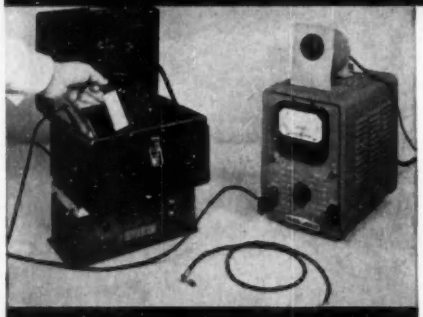
*Reg. U.S. Pat. Off.

FOXBORO
REG. U.S. PAT. OFF.
Analytical Instrumentation

THE RECORDING THAT WASN'T

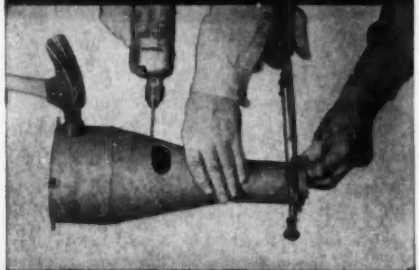
... It's happened to lots of magnetic tape users





Test factually demonstrates shielding effectiveness of Netic alloy material and enclosure design. Instrumentation used: magnetic field radiating source, AC vacuum tube voltmeter, Variac, pickup probe and Netic Tape Data Preserver. For complete test details and results, request Data Sheet 142.

For safe, distortion-free storage of large quantities of vital magnetic tapes. Designed for Military Establishments, Radio & TV Broadcasters, Automated Plants, Libraries, Laboratories, Gov't. Agencies, etc.



Composite photo demonstrating that magnetic shielding qualities of NETIC alloy material are not affected by vibration, shock (including dropping) etc. Furthermore, NETIC does not retain residual magnetism nor require periodic annealing.

Maybe you've been one of these unfortunates . . . who've spent thousands of dollars . . . plus many man hours . . . to record valuable information on magnetic tapes . . . only to find the data useless from accidental distortion or erasure.

Unexpected exposure to an unpredicted magnetic field, and presto!—your valuable data is filled with irritating odd noises. Distortions may result in virtual data erasure.

Unprepared tape users never realize the danger of loss until it's too late.

Such losses have become increasingly common from damaging magnetic fields during transportation or storage. These fields may be produced by airplane radar or generating equipment or other power accessories. Also by generators, power lines, power supplies, motors, transformers, welding machines, magnetic tables on surface grinders, magnetic chucks, degaussers, solenoids, etc.

Since 1956, many military and commercial tape users successfully avoid such unpleasant surprises. Their solution is shipping and storing valuable tapes in sturdy NETIC Tape Data Preservers.

Data remains clear, distinct and distortion-free in NETIC Preservers. Original recorded fidelity is permanently maintained.

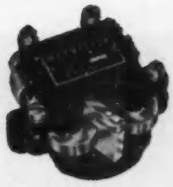
Don't take chances with *your* valuable magnetic tapes. Keep them *permanently clear* and *distinct* for *every* year of their useful life in dependable NETIC Preservers. Can be supplied in virtually any size and shape to your requirement. Write for further details today.

For complete, distortion-free protection of valuable tapes during transportation or storage. Single or multiple containers available in many convenient sizes or shapes.

MAGNETIC SHIELD DIVISION PERFECTION MICA CO.

1322 No. Elston Avenue, Chicago 22, Illinois

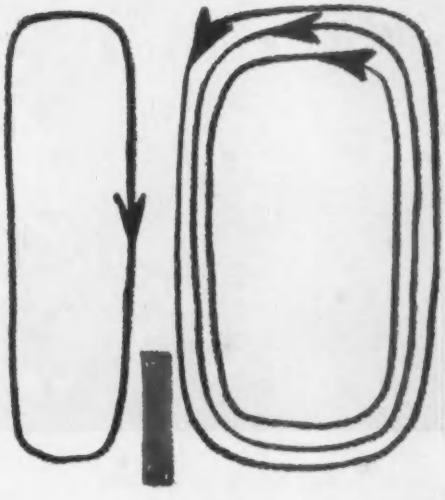
Originators of Permanently Effective Netic Co-Netic Magnetic Shielding



Metrisite...is the only device available today

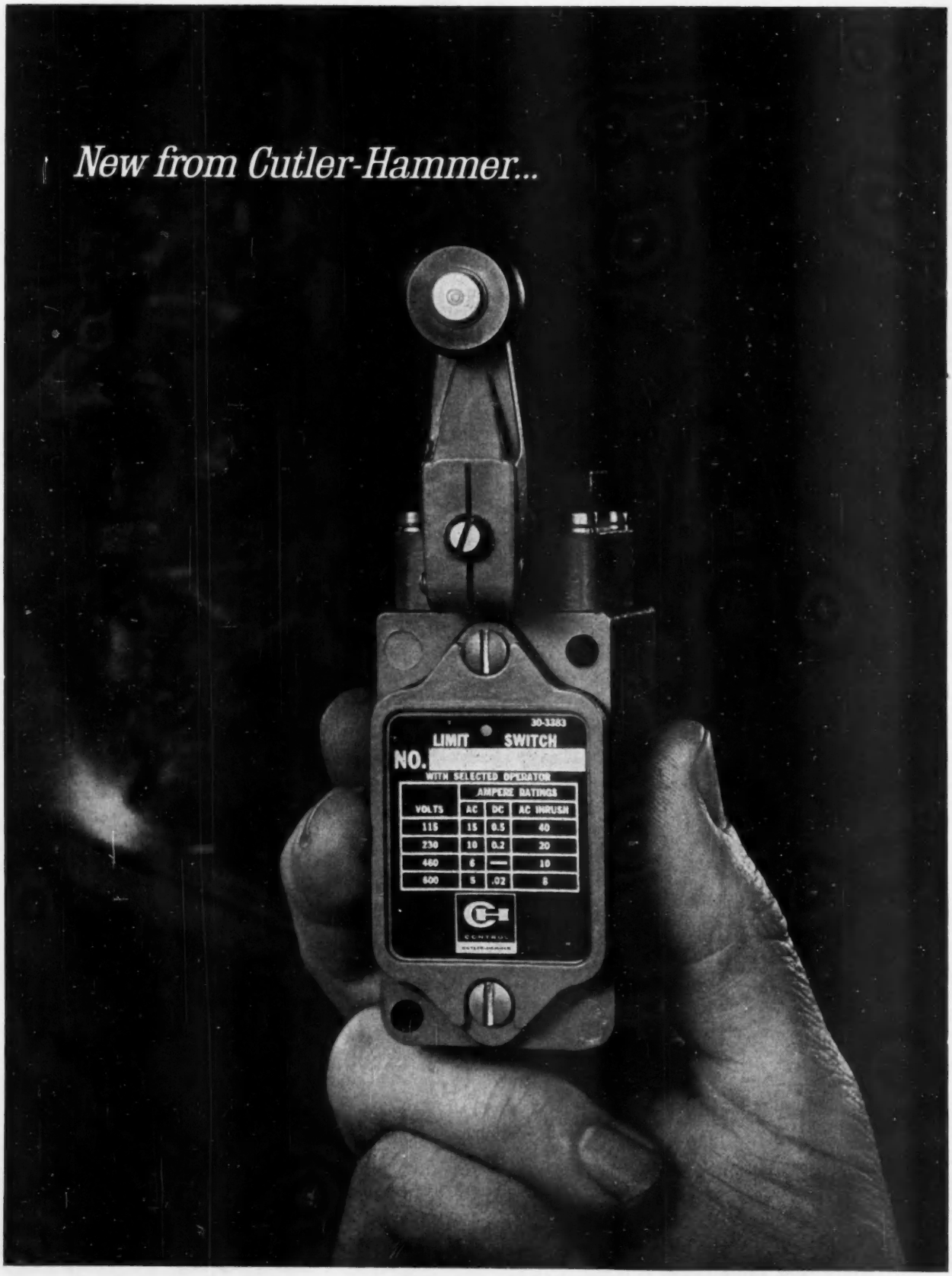
that provides a near-perfect combination of ideal transducer characteristics. The unusual properties of this remarkable new motion-sensing development are: extreme resolution...

easily measures one ten-millionth of an inch; minute operating force...absolute minimum bearing friction; negligible reactive force... a fraction of a milligram; true linearity...a proven accuracy of 1/10%; high electrical output...up to 100 volts without amplification; wide range of shapes and sizes...from sub-miniature on up; exceptional ruggedness...can meet military shock and vibration tests. Now, many of the obstacles that have plagued control technology can be eliminated. Write for Metrisite details.



brush INSTRUMENTS
DIVISION OF
37TH AND PERKINS CLEVITE CORPORATION CLEVELAND 14, OHIO

CIRCLE 59 ON READER SERVICE CARD


New from Cutler-Hammer...
30-3383
LIMIT SWITCH
NO.
WITH SELECTED OPERATOR
AMPERE RATINGS
VOLTS
AC
DC
AC INRUSH
115
15
0.5
40
230
10
0.2
20
460
6
—
10
600
5
.02
5
CONTROL

37TH AND PERKINS CLEVITE CORPORATION CLEVELAND 14, OHIO

CIRCLE 59 ON READER SERVICE CARD

Now! A limit switch with more than twice the life of any other type made!

Cutler-Hammer's new oil tight limit switch cuts the biggest cause of machine tool electrical failures in half

Limit switch failure has caused more production down time than any other electrical component. Now, Cutler-Hammer has the best cure yet for this big industrial headache—the most reliable limit switch made.

Under test conditions so tough they'd never be equalled in actual production, it has lasted more than twice as long as the best of competition. Be sure to send for Pub. ED143-A200 for complete information.

Cutler-Hammer is on the move, and this new limit switch is just one of many examples.

You can see this new power in new products, in new engineering depth, particularly in industrial automation. Our Airborne Instruments Laboratory Division, for instance, adds electronic experience to the advanced control engineering which has put us into a position of leadership throughout the world. We've developed systems that automatically handle everything from charging a blast furnace to counting and stacking newspapers. We've added plants to give us more manufacturing capacity.

The new trademark you see here represents our new capability to help you meet the tremendous demands that you are going to face in the years ahead. We want to help you plan ahead so you can keep ahead.

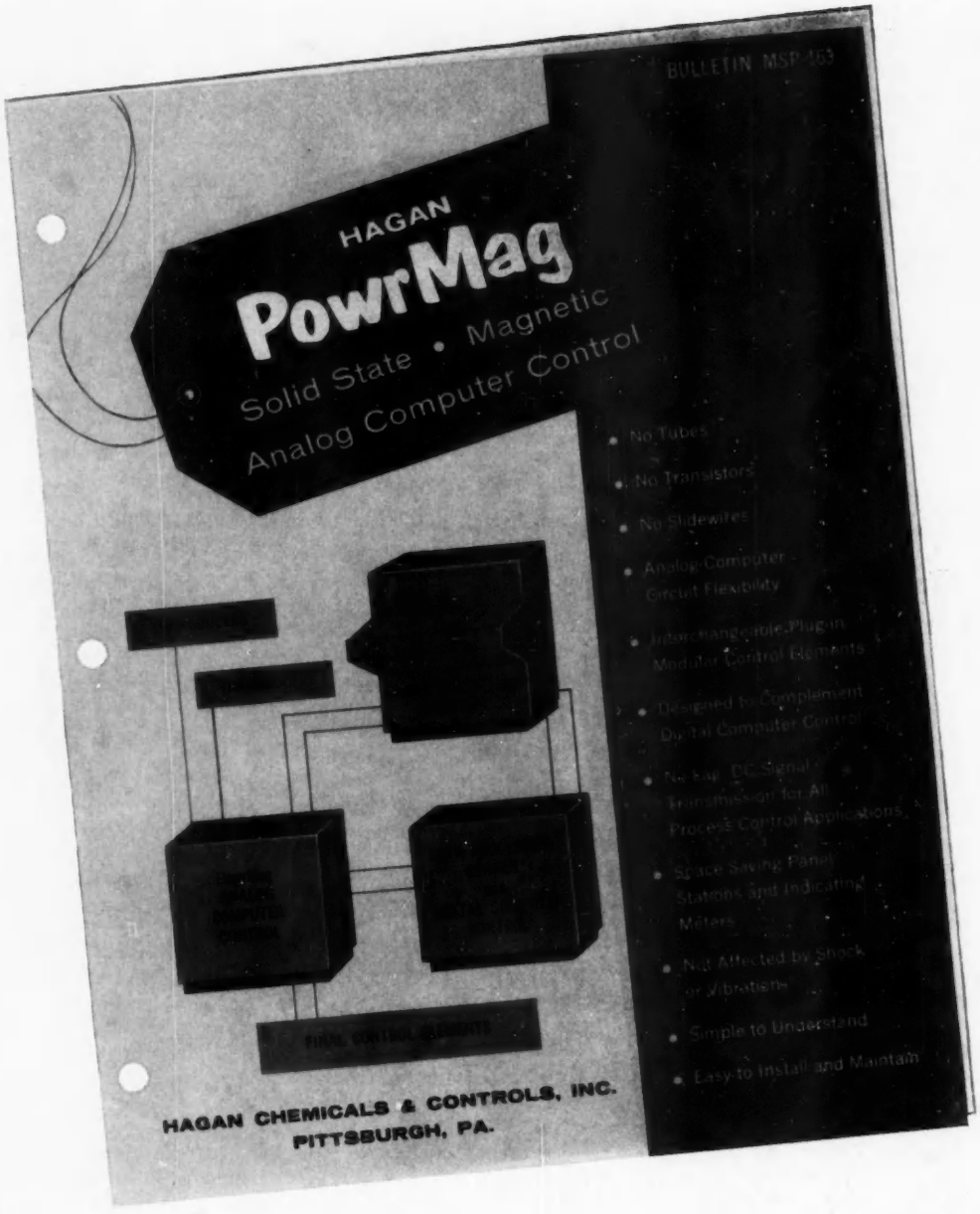
Phone your nearest Cutler-Hammer office now and let us tell you our story.

WHAT'S NEW? ASK...

CUTLER-HAMMER

Cutler-Hammer Inc., Milwaukee, Wis. • Division: Airborne Instruments Laboratory • Subsidiary: Cutler-Hammer International, C. A. Associates: Canadian Cutler-Hammer, Ltd.; Cutler-Hammer Mexicana, S. A.; Intercontinental Electronics Corporation.

CIRCLE 61 ON READER SERVICE CARD


BULLETIN MSP-163
HAGAN
PowrMag
Solid State • Magnetic
Analog Computer Control
• No Tubes
• No Transistors
• No Slidewires
• Analog Computer Circuit Flexibility
• Interchangeable Plug-in Modular Control Elements
• Designed to Complement Digital Computer Control
• No Low DC Signal Transmission for All Process Control Applications
• Space Saving Panel Stations and Indicating Meters
• Not Affected by Shock or Vibration
• Simple to Understand
• Easy to Install and Maintain
HAGAN CHEMICALS & CONTROLS, INC.
PITTSBURGH, PA.

Send for this bulletin. Hagan's PowrMag analog computer control offers the highest degree of flexibility yet devised for industrial control. A new bulletin, MSP-163, shown above, gives full details on the system, the magnetic control units, the patchboard, and provides useful information on determining computer requirements.

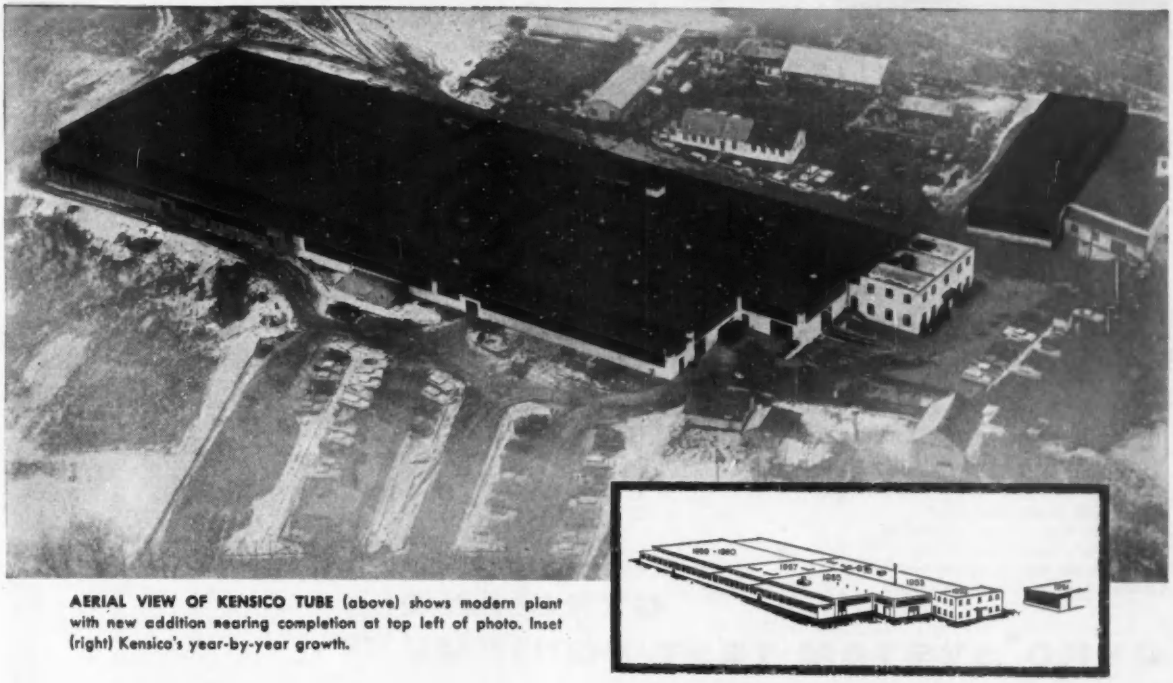
HAGAN CHEMICALS & CONTROLS, INC.

DIVISIONS: CALGON COMPANY, HALL LABORATORIES

HAGAN BUILDING, PITTSBURGH 30, PA.
In Canada: Hagan Corporation (Canada) Limited, Toronto
European Division: Via Flumendosa No. 13, Milano, Italy

SEND FOR YOUR FREE COPY TODAY

SET FOR THE SOARING SIXTIES



AERIAL VIEW OF KENSICO TUBE (above) shows modern plant with new addition nearing completion at top left of photo. Inset (right) Kensico's year-by-year growth.

PACE-SETTER during a period of phenomenal growth in northern Westchester County, N. Y. Kensico Tube is Mt. Kisco's largest manufacturing business. Products include: hard and soft copper water tube; copper air conditioning, refrigeration and instrumentation tube; and copper tubing for propane gas lines, heat exchangers, automotive and industrial applications. Now, after more than a decade of corporate growth and expansion of production and marketing facilities, Kensico is set to meet the challenge of the SOARING SIXTIES.

IN 1950, CONSTRUCTION of first new building was started. Kensico had been chartered under N. Y. State Law in 1945. Under present management since 1948. Until 1951, company was located in an old cider mill which it leased (floor space 8500 sq. ft.).

TODAY, AFTER PUTTING UP 4 MORE ADDITIONS, Kensico has more than 60,000 square feet of modern fireproof plant and office space.

BY SPRING, 1960, Kensico expects to complete a new 40,000 square foot addition to the plant. Total plant and office space will then exceed 100,000 square feet.

PRODUCTION HAS INCREASED with each addition since 1950. It will be still further increased in both capacity and range of sizes by the new 1960 addition.

IN THE TEN YEAR PERIOD, 1950-1960, Kensico has had a 7-fold growth in gross sales..

EFFECTIVE FEBRUARY 1st 1960, Kensico Tube Company Incorporated, Mt. Kisco, N. Y., merged with Robinson Technical Products, Inc., Teterboro, N. J. Robinson also has other corporate facilities at Hingham, Mass., and Santa Monica, California. The merger strengthens Kensico's position in engineering and metallurgy and places new technological know-how and experience at the disposal of Kensico's customers. Kensico's new name is KENSICO TUBE COMPANY DIVISION — ROBINSON TECHNICAL PRODUCTS, INC.

Kensico Tube
COMPANY DIVISION
Robinson Technical Products, Inc.

MOUNT KISCO, NEW YORK

Kensico Products are also Available Through Warehouse Distributors and Sales Representatives in Cambridge, Mass.; Middlebury, Conn.; Buffalo, N. Y.; Lindenhurst, N. Y.; Goshen, N. Y.; Roselle, N. J.; Philadelphia, Pa.; Flourtown, Pa.; Pittsburgh, Pa.; Cleveland, Ohio; Detroit, Mich.; Evanston, Ill.; St. Louis, Mo.; Milwaukee, Wisc.; Durham, N. C.; Berwyn, Ill.; Ft. Lauderdale, Fla.; St. Petersburg, Fla.

Reeves INSTRUMENT CORPORATION

first in today's front page developments

GYRO TEST CONSOLE *(GTS-1001C)* First fully equipped COMPLETE test facility for testing of single axis integrating gyros. Can also be adapted for testing precision floated accelerometers.

GYRO TEST TABLE *(Model RD)* Positioning data accuracy guaranteed to 2 sec. arc. Complete electronics for testing any type of inertial gyro or complete inertial reference packages.

GYRO AND GYRO SYSTEM TEST EQUIPMENT

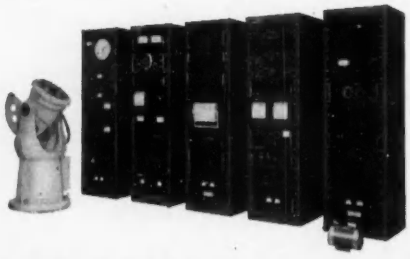
for today's front page missile programs

Reeves' research and development in the field of precision gyros has always paced the industry, resulting in over ten years of high level gyro production, based on exacting reliability standards subject to the most exhaustive quality control. Today's gyros and gyro systems demand high precision test equipment far beyond the capabilities of commercially available instruments. To meet this need, Reeves has specified, designed, and *built* test equipment capable of meeting the most stringent requirements — not only for today, but for the foreseeable future as well.

Through the years, this test equipment has been refined and packaged to the point where we now can present with confidence the most accurate and comprehensive line of gyro test equipment available.

DIFFERENTIAL WATTMETER High precision test detection of extremely small power consumption differentials in gyro spin motors and other types of rotating components.

superbly precise . . . fast, simplified operation . . . maximum reliability



TYPICAL ELECTRONICS GROUP for inertial reference package system test. All Reeves equipment offers Laboratory accuracy with production line practicality.

This equipment has numerous practical advantages for producers and users of gyros and gyro systems. Exceptional accuracy and flexibility permit rapid testing of today's most advanced gyros and inertial reference packages, as well as tomorrow's even more advanced designs.

Ease and reliability of operation, along with intelligent human engineering, allow for rapid training of equipment operators. Production quantities can be tested with laboratory precision.

Simplified maintenance and service assure against costly down-time.

Write on company letterhead for complete data file No. 104.

ENGINEERS:

Rewarding careers at Reeves in the fields of radar, guidance, and computer systems.

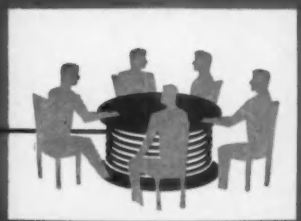
REEVES INSTRUMENT CORPORATION

A Subsidiary of Dynamics Corporation of America—Roosevelt Field, Garden City, New York

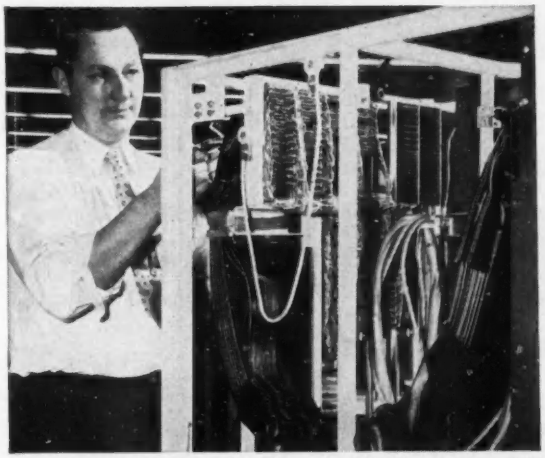
Reeves INSTRUMENT CORPORATION

DU PONT

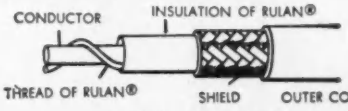
WIRE AND CABLE ROUND TABLE



Flame-retardant insulation of RULAN® used by IBM has five outstanding qualities



Approximately 1000 feet of cable are installed in each new IBM 7090 computer. Only the most dependable of insulating materials could meet the rigid requirements.



The unique design consists of a thread of RULAN spiraled around the conductor to provide for an air space between the conductor and insulation.

IBM's new 7090 fully transistorized data-processing system is the most powerful system to be marketed commercially. It has computing speeds more than six times faster than previous systems...can read and write 3,000,000 bits of information a second.

AN air-spaced ribbon cable, insulated with Du Pont RULAN flame-retardant plastic, is used in the new 7090 Data Processing System, manufactured at the huge IBM plant in Poughkeepsie, N. Y. Performing such feats as reading and writing three million units of information a second, the 7090 relies heavily upon its electrical system. IBM selected a dependable cable insulated with RULAN, developed and manufactured by William Brand—Rex Division of American Enka Corporation, Concord, Massachusetts.

The most important consideration is the flame retardance of the insulation of RULAN. The possibility of fire in such an important and expensive machine, although slight, is not worth risking. Thus this insulation, with an excellent self-extinguishing capacity, proved acceptable. RULAN was also chosen because it has a low dielectric constant over a wide frequency range. Its excellent dielectric properties give RULAN still another useful quality—it can be thinner than many other materials.

Because the installation required that the cable bend around corners, it had to be flexible and have a good radius of bend. Again RULAN proved wholly acceptable. With approximately 1000 feet of cable installed in each machine, cost is an important consideration. And RULAN proved to be lower in cost than other suitable materials with the same properties.

You may find one of the Du Pont plastics will help you solve your wire and cable problems. Find out how by writing to your wire and cable supplier, or to: E. I. du Pont de Nemours & Co. (Inc.), Dept. E-4, Room 2507A Nemours Building, Wilmington 98, Delaware.

Du Pont does not manufacture wire and cable, but supplies thermoplastic resins for insulation and jacketing.

POLYCHEMICALS DEPARTMENT

DU PONT
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BETTER THINGS FOR BETTER LIVING...*THROUGH CHEMISTRY*

ALATHON® POLYETHYLENE RESINS | **RULAN®** FLAME-RETARDANT PLASTICS | **ZYTEL®** NYLON RESINS

available from
inventory for
immediate delivery–
silicon transistors with

400 mw POWER DISSIPATION

@25°C in free air!

All electrodes completely insulated from the JEDEC-30 package (TO-5)

These Hughes PNP fused junction silicon transistors...which are especially recommended for small signal current gain, DC amplifier and other applications...offer you the following advantages over competitive devices:

• BV_{CBO}, BV_{EBO}, and BV_{CEO} are symmetrical • lower leakage current • controlled gain band • lower saturation resistance • higher operating frequency

You receive still another benefit from these Hughes silicon transistors: proven reliability. Its reliability life tests at maximum operating temperature show a reliability factor of 4×10^{-5} or only one failure in 25,000 transistor hours of operating life.

Order today! These Hughes transistors are available from inventory at both the factory and at all Hughes distributors. Just call or write your nearest Hughes Semiconductor Sales office or distributor.

Specifications

Type	BV_{EBO} BV_{CBO} BV_{CEO}	H_{fe} Min.	H_{fe} Max.	Max. V_{CE} @ I_C=10ma @ I_B=2ma	Maximum I_{CBO}* and I_{EBO}*	Typ. F ∝ b (MC)
2N1228	–15V	14	32	–0.2	–0.1μA	1.2
2N1229	–15V	28	65	–0.2	–0.1μA	1.2
2N1230	–35V	14	32	–0.2	–0.1μA	1.2
2N1231	–35V	28	65	–0.2	–0.1μA	1.2
2N1232	–60V	14	32	–0.2	–0.1μA	1.0
2N1233	–60V	28	65	–0.2	–0.1μA	1.0
2N1234	–110V	14	32	–0.2	–0.1μA	0.8

ALSO AVAILABLE WITH 1 WATT POWER DISSIPATION IN COAXIAL PACKAGE

*AT 80% OF MAXIMUM VOLTAGE

SEMICONDUCTOR DIVISION

Creating a new world with ELECTRONICS

HUGHES PRODUCTS

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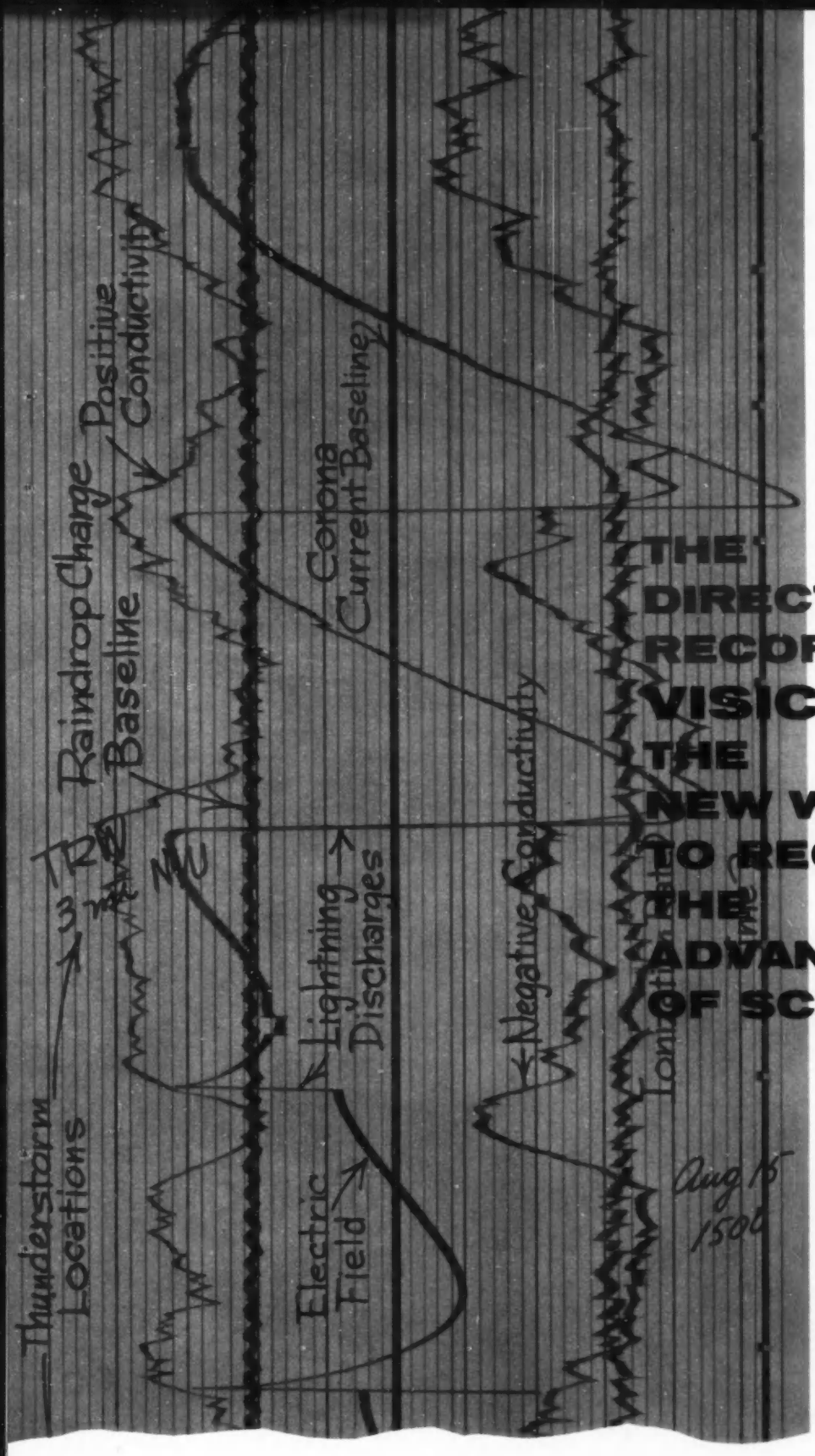
CIRCLE 66 ON READER SERVICE CARD

CIRCLE 67 ON READER SERVICE CARD→



THE DIRECT RECORDING VISICORDER... THE NEW WAY TO RECORD THE ADVANCEMENTS OF SCIENCE

HONEYWELL DEVELOPERS OF THE ULTRA-VIOLET PRINCIPLE OF OSCILLOGRAPHY, PRESENT THREE VERSATILE VISICORDER MODELS AND ASSOCIATED SIGNAL-CONDITIONING EQUIPMENT...

Honeywell

MODEL 906 VISICORDER

. . . pioneer in the field of Ultra-Violet direct recording

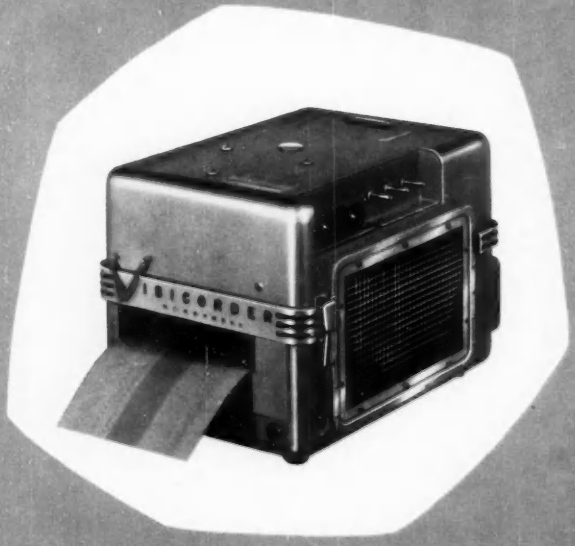
Two models of the 906 Series Visicorder give you a choice of recording capacity on 6″ paper.

The Model 906 B-1 uses high-sensitivity Series M sub-miniature plug-in type galvanometers that are directly interchangeable among all Honeywell oscillographs of the sub-miniature galvanometer type. Optical arms, therefore galvanometer sensitivities, are an identical 11.8 inches in all instruments.

The 906 B-1 provides for 14 channels of recording including two static reference traces —each channel operating at frequencies from DC to 5000 cps. It has provisions for recording intensity control; trace identification; grid line system (either inches or millimeters) and selectable record speeds (a choice of 5 interchangeable systems, each covering 4 speeds).

The Model 906 B-2 is identical to the 906 B-1, except that it uses solid-frame galvanometers with a capacity of 8 channels, including 2 timing or event-marking channels.

Accessories available for both models of the 906 B include a record take-up unit; record takeup and latensifier; relay rack adapters; and the Visicorder Timing Unit.



Honeywell

MODEL 1108 VISICORDER

. . . newest of the Honeywell direct-recording oscillographs

The Model 1108 delivers direct-writing Visicorder oscillography at the lowest cost per channel. Intermediate in size between the 14-channel 906 and the 36-channel 1012, the 1108 simultaneously records up to 24 channels of data on a record 8 inches wide. This instrument, like other Visicorders, records at frequencies from DC to 5000 cps with unparalleled galvanometer sensitivities.

Pushbutton controls give a choice of 15 record speeds from .05 to 80 inches per second, and time line intervals of 1, .1 and .01 seconds. Such built-in features as automatic record length control, grid-line intensity control, galvanometer spot intensity control, record numbering, reversible record drive, trace identification, provision for remote operation, and many others contribute to maximum convenience in recording high-speed analog data.

As in all Honeywell Visicorders, paper loading, access to the interior, and galvanometer adjustment is easy and convenient.

Honeywell

MODEL 1012 VISICORDER

. . . the most complete, convenient multi-channel oscillograph on the market today

The Model 1012 has been accepted as "the most versatile instrument ever devised for converting dynamic data into immediately visible read-out." It will record up to 36 channels of data simultaneously on 12″ wide paper. It gives complete push-button control of 15 different paper speeds, from 0.1 to 160 in./sec., with automatic recording intensity control. Designed into the 1012 are many other convenience features: daylight paper loading; reversible record drive choice; switch selection of 5 different timing intervals (.001 to 10.0 seconds); simultaneous recording of amplitude reference (grid) lines; trace identification; automatic record length control; record numbering; jump-speed control and provisions for remote and/or multiplexed operation.

Like other Visicorders, the 1012 makes use of the sub-miniature galvanometer. All instruments are readily adaptable to rack and shock-mounting.

Honeywell

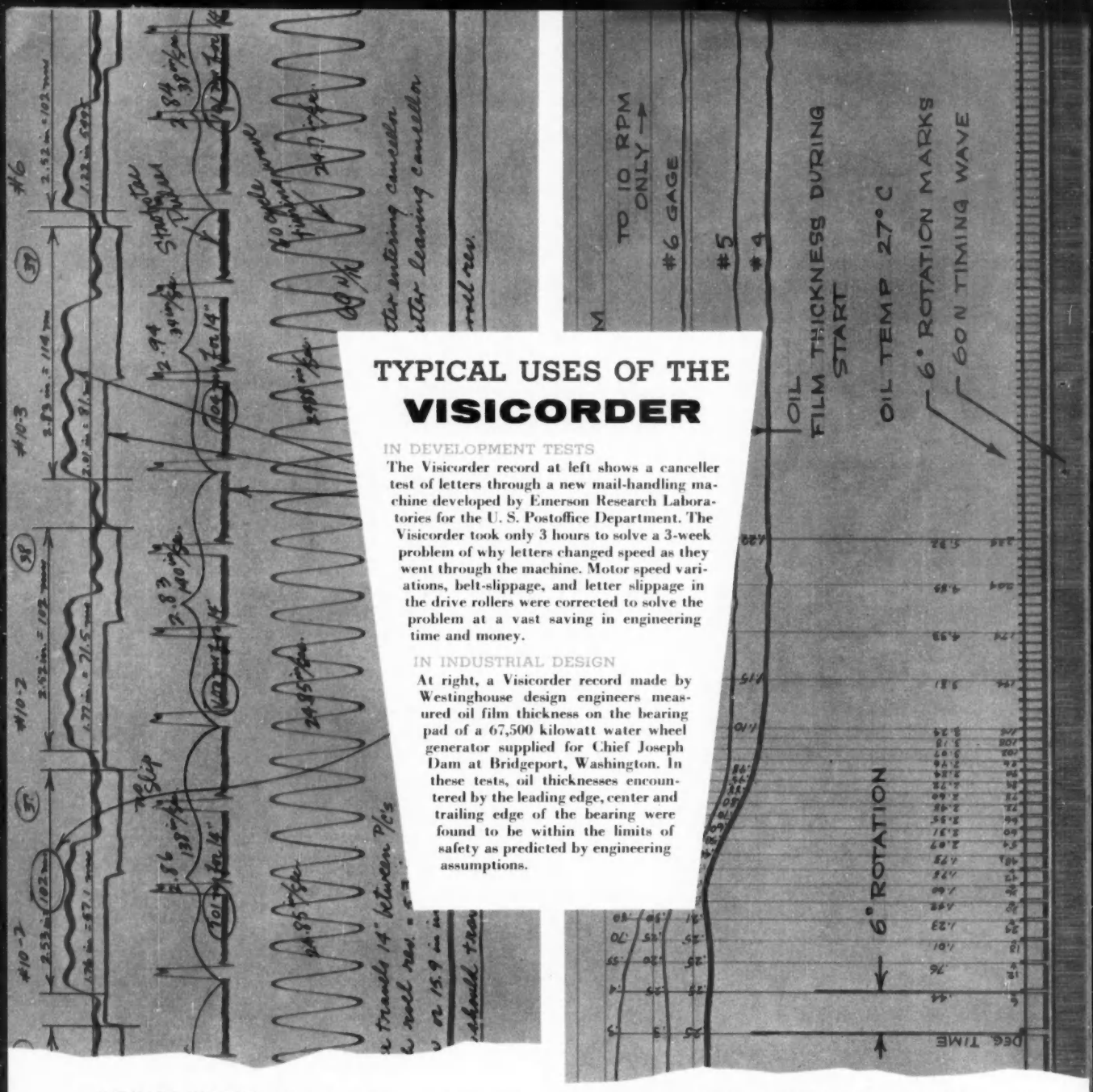
SIGNAL-CONDITIONING SYSTEMS

A. The Model 119 Amplifier System . . . a simple and accurate 6-channel carrier amplifier, for use in oscillographic recording, which may be converted to a linear/integrating system simply by installing linear/integrating channels in the same case. The carrier amplifier is designed to amplify signals from resistive, variable-reluctance, differential-transformer, and capacitive transducers. The linear/integrate amplifier is used in conjunction with self-generating transducers such as vibration pickups, etc. The carrier system provides recordings in the 0-1000 cps range at galvanometer amplitudes of 8″ peak-to-peak. The linear-integrate system accommodates frequencies from 5-5000 cps.

B. The Model 130-2C Carrier Amplifier . . . a two-channel unit for use with resistance, reluctance, differential transformer, and capacitive transducers. Produces 8-inch (peak-to-peak) galvanometer deflections up to 1000 cps from as little as 0.5 mv gage output.

C. The Model 82-6 Bridge Balance and Strain Indicator . . . a simple, accurate 6-channel unit for calibrating, balancing, controlling, and measuring static and dynamic phenomena from resistive transducers.

All three of these units are suitable for convenient rack mounting.



TYPICAL USES OF THE VISICORDER

IN DEVELOPMENT TESTS

The Visicorder record at left shows a canceller test of letters through a new mail-handling machine developed by Emerson Research Laboratories for the U. S. Postoffice Department. The Visicorder took only 3 hours to solve a 3-week problem of why letters changed speed as they went through the machine. Motor speed variations, belt-slippage, and letter slippage in the drive rollers were corrected to solve the problem at a vast saving in engineering time and money.

IN INDUSTRIAL DESIGN

At right, a Visicorder record made by Westinghouse design engineers measured oil film thickness on the bearing pad of a 67,500 kilowatt water wheel generator supplied for Chief Joseph Dam at Bridgeport, Washington. In these tests, oil thicknesses encountered by the leading edge, center and trailing edge of the bearing were found to be within the limits of safety as predicted by engineering assumptions.

OTHER USES of the Visicorder . . . as a direct readout unit **IN RECORDING AND MONITORING SYSTEMS** . . . **IN MISSILE AND ENGINE ANALYSIS** for test stand recording . . . for analog recording **OF TELEMETERED SIGNALS** . . . **IN CONTROL** to monitor reference and error signals . . . **IN NUCLEAR TEST** to record temperatures, pressures, impacts, etc. . . . **IN LABORATORIES** for all-purpose analysis . . . **IN PRODUCTION** for final dynamic inspection . . . **IN COMPUTING** for immediately-readable analog records . . . **IN PILOT COMPONENT TESTS** for rapid evaluation of prototypes . . . **IN ALL TESTS** which are non-repetitive in sequence, making oscilloscopes impractical.

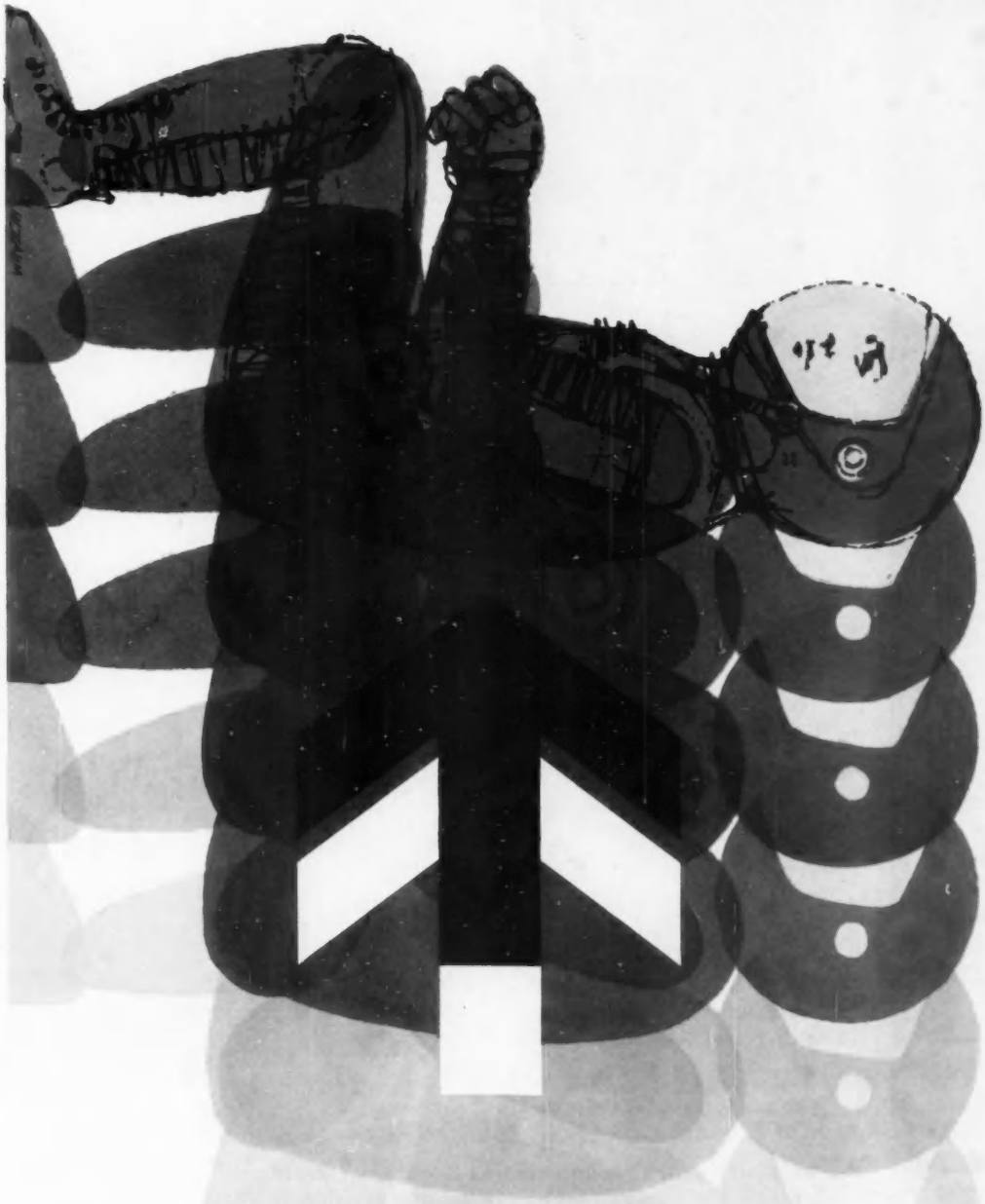
Write for your *free* copy of the new 36-page Visicorder Applications Manual, a comprehensive, detailed guidebook to many varied uses of the Visicorder.

Honeywell

Industrial Products Group

For further information including prices and delivery, write
Minneapolis-Honeywell Regulator Company, Industrial Products Group, Heiland Division, 5200 E. Evans Ave., Denver 22, Colorado.

MAN OUT...



MARTIN-DESIGNED CIRCULAR SPACE COMPUTERS ARE AVAILABLE **FREE** TO INTERESTED PERSONS BY WRITING TO THE SAME ADDRESS.

A fascinating project at Martin-Denver and one which offers to the truly creative engineer or scientist a personal esteem and professional recognition unequalled in today's opportunities. Please do consider being a part of this or other creative involvements at Martin-Denver and inquire of N. M. Pagan, Director of Technical and Scientific Staffing, (Dept. 1B), The Martin Company, P. O. Box 179, Denver 1, Colo.

MARTIN
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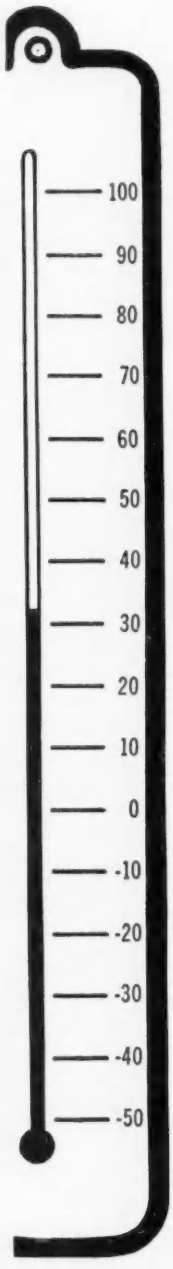


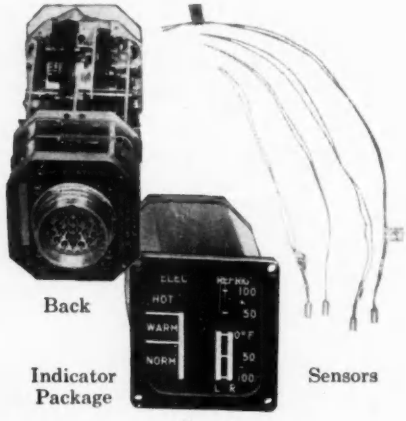
1 or 6 . . .

How do you take the temperature of an electronic system?

Use ONE Compact, Accurate, Lightweight, Completely Transistorized Oster-Developed Temperature Indicating System. Replaces 6 Indicating Systems.

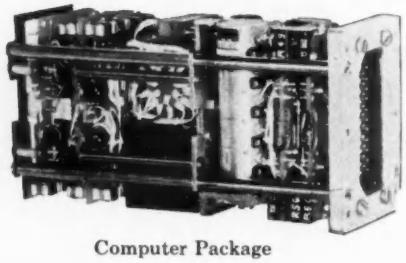
The device illustrated senses and displays the highest of 4 temperature sensor signals on the Convair B-58 supersonic bomber. It also reads out the temperature of the plane's 2 refrigeration systems. However, the unit can monitor temperature of any military or commercial electronic system. Special versions can be furnished to monitor any analog voltage signal.

Oster®



Entire unit (component parts illustrated) has an accuracy of 1½%, weighs only 3.85 lbs. max., requires only 2⅜" panel space, and does the work of 6 indicating systems. Component parts consist of 4 sensors, a computer package with 6 channels, and a hermetically sealed indicator package.

The unit is typical of Oster designed equipment.



Computer Package

For help with your instrumentation and display problems, talk to the specialists at the Avionic Division.

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OTHER PRODUCTS INCLUDE:

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John Oster **MANUFACTURING CO.**

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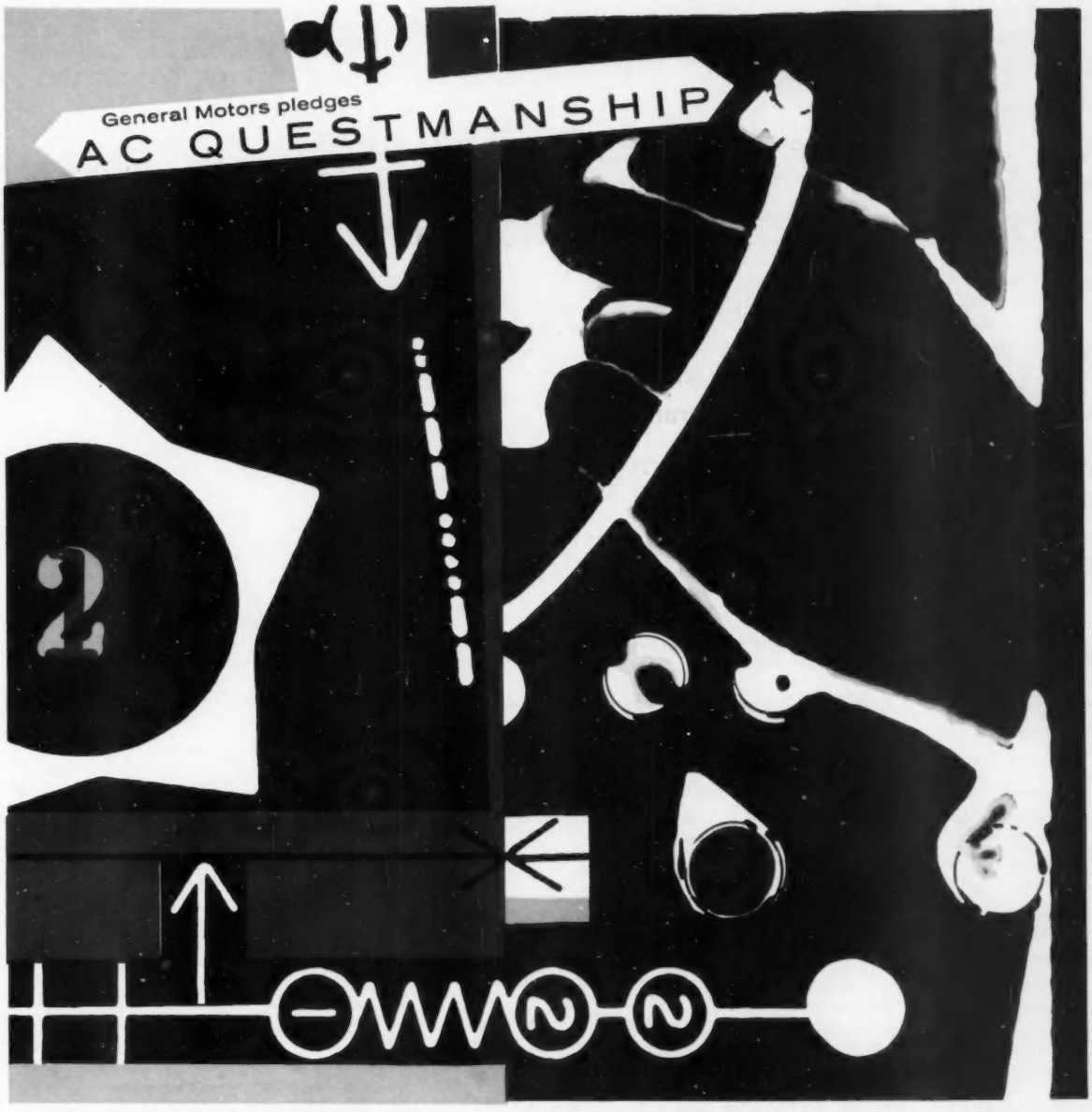
Engineers For Advanced Projects: Interesting, varied work on designing transistor circuits and servo mechanisms.
Contact Mr. Robert Burns, Personnel Manager, in confidence.



AC Seeks and Solves the Significant—Inspired by GM's pledge to contribute heavily to our national defense, AC, an acknowledged leader in the new technology, plans to reach far beyond such accomplishments as AChiever inertial guidance systems. / This is AC QUESTMANSHIP. It's an exciting scientific quest for new ideas, components and systems . . . to promote AC's challenging projects in guidance, navigation, control and detection. / Mr. Jack Briner, AC Director of Field Service, believes his department's Career Development Program "offers young engineers world-wide opportunities in the practice of Questmanship." They learn a product from its technological theory through its operational deployment. Following this training, "they utilize their own ingenuity to support AC products in the field, with more effective technical liaison through training, publications, maintenance engineering, and logistics." / You may qualify for this special training, if you have a B.S. in the electronics, scientific, electrical or mechanical fields. Special opportunities also exist at AC for men with M.S. and Ph.D. degrees. If you are a "seeker and solver," write the Director of Scientific and Professional Employment, Mr. Robert Allen, Oak Creek Plant, Box 746, South Milwaukee, Wisconsin.

GUIDANCE / NAVIGATION / CONTROL / DETECTION / AC SPARK PLUG *The Electronics Division of General Motors*

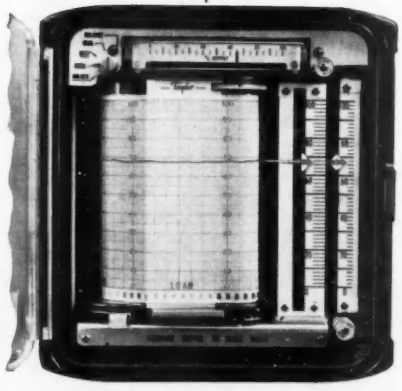
707 means Jet Travel, but...

TAYLOR 707T MEANS SIMPLEST, MOST DEPENDABLE FLOW MEASUREMENT

No. 707T Electronic DP Transmitter has no vacuum tubes — no transistors

Users of this instrument claim it is the finest flow transmitter ever designed. It provides the widest possible flexibility, sustained long-term accuracy and performance because:

- **Simplest Conversion** from differential pressure to 0-200mv AC.
- **Nothing exposed to the process** except end plates (steel or 316 stainless steel) and 316 stainless steel diaphragms.
- **Minimum displacement**—only .025 of a cubic inch of fluid for 100" range. Permits DP measurement even when solids are present.
- **Internal silicone damping**—continuously adjustable to damp out pulsations from 5 to 100 cpm.
- **Full over-range protection to 1500 psi**—either high or low sides.
- **Range span continuously adjustable** from 0 to 50" water to 0 to 200" water, using output voltage adjustment.
- **External zero adjustment**, with wide range of zero suppression.



Compatible No. 700J AC or DC Electronic Recorder

- **Powerful servo motor** provides accuracy of ½ of 1%, sensitivity to changes of 0.1% in input signal.
- **High energy servo motor** permits heavy duty, integral alarms.
- **Big 4" chart** gives continuous 30-day record (1" per hr.). "Adjust-O-Matic" 24-hr. chart tear-off, optional.
- **Available with one,** two or three pen recording.
- **Completely transistorized,** unaffected by ±10% line voltage variation.

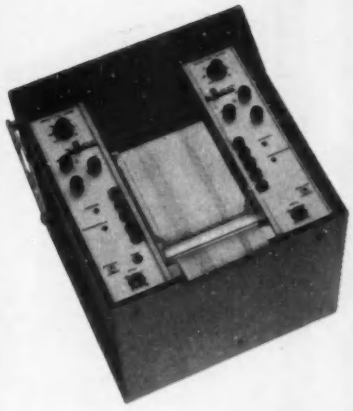
For full information about these outstanding instruments, call your Taylor Field Engineer, or write for Bulletin 98333 (707T) or Bulletin 98335 (700J). Taylor Instrument Companies, Rochester, N. Y., or Toronto, Ont.

Taylor Instruments **MEAN ACCURACY FIRST**

keep an accurate graphic record

OF RESEARCH, DESIGN, TEST DATA

two channels



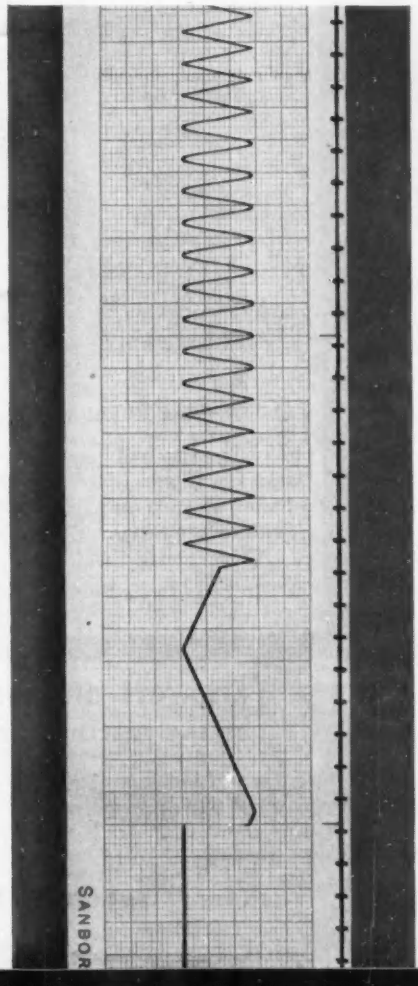
For General Purpose DC Recording — Model 320

For recording *two variables* simultaneously, the Model 320 provides a versatile, transistorized amplifier for each input signal. The rugged 2-channel recorder assembly has heated stylus recording on two *50 mm wide* rectangular coordinate channels, 4 pushbutton chart speeds, and 6 inches of visible chart. The Recorder can be placed vertically, horizontally or at a 20° angle.

MODEL 320 SPECIFICATIONS

Sensitivity: 0.5, 1, 2, 5, 10, 20 mv/mm and v/cm
Frequency Response: 3 db down at 125 cps, 10 mm peak-to-peak
Common Mode Voltage: ±500 volts max.
Common Mode Rejection: 140 db min. DC
Calibration: 10 mv internal ±1%
Output Connectors for each channel accept external monitoring 'scope or meter

NEW SANBORN PORTABLE DIRECT WRITING RECORDERS FOR IN-PLANT, LABORATORY OR FIELD RECORDING



Two models of this 21 lb. brief case size recorder are available — Model 301 for AC strain gage recording, Model 299 for general purpose DC recording. Both provide immediately visible, inkless traces by heated stylus on 40 division rectangular coordinate charts . . . frequency response to 100 cps . . . 5 and 50 mm/sec chart speeds . . . approx. 4 inches of record visible in top panel window.

single channel

MODEL 301 SPECIFICATIONS

The amplifier section of the Model 301 is an all-transistorized carrier type with phase sensitive demodulator. The power supply and internal oscillator circuits are also transistorized.
Sensitivity: 10 uv rms/div (from transducer)
Attenuator Ratios: 2, 5, 10, 20, 50, 100, 200
Carrier Frequency: 2400 cps internal
Transducer Impedance: 100 ohms min.
Calibration: 40 uv/volt of excitation
Output Connector: for external monitoring 'scope or meter

MODEL 299 SPECIFICATIONS

Combines the dependability of transistors with the high input impedance of vacuum tubes for reliable broad-band DC recording.
Sensitivity: 10, 20, 50, 100, 200, 500 mv/div and 1, 2, 5 and 10 v/div
Input Resistance: 5 megohms balanced each side to ground
Common Mode Voltage: ±2.5 volts max. at 10 mv/div sensitivity increasing to ±500 volts max. at other sensitivities
Common Mode Rejection: 50:1 most sensitive range
Calibration: 0.2 volt internal ±1%
Output Connector: for external monitoring 'scope or meter

Contact your Sanborn Sales-Engineering representative for complete information, or write the main office in Waltham. Sales-Engineering representatives are located in principal cities throughout the United States, Canada and foreign countries.

SANBORN COMPANY
INDUSTRIAL DIVISION
175 Wyman Street, Waltham 54, Mass.

CIRCLE 75 ON READER SERVICE CARD

BASIC BUILDING BLOCKS FROM KEARFOTT

ELECTROHYDRAULIC SERVO VALVE

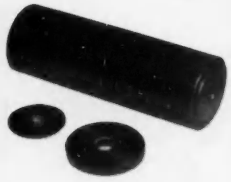
Kearfott's unique approach to electrohydraulic feedback amplification design has resulted in a high-performance miniature servo valve with just two moving parts. Ideally suited to missile, aircraft and industrial applications, these anti-clogging, 2-stage, 4-way selector valves provide high frequency response and proved reliability even with highly contaminated fluids and under conditions of extreme temperature.

TYPICAL CHARACTERISTICS

Quiescent Flow	0.15 gpm
Hysteresis	3% of rated current
Frequency Response	3 db @ 100 cps
Supply pressure	500 to 3000 psi
Temperature-Fluid & Ambient	−65° F to +275° F
Flow Rate Range	.3 to 10 gpm
Weight	10.5 ounces

Write for complete data.

BASIC BUILDING BLOCKS FROM KEARFOTT



FERRITES

Kearfott's Solid State Physics Laboratory formulates, fires and machines permanent magnet ferrite materials of various compositions. Typical high-efficiency array utilizes Kearfott PM-3 ferrite material with specially designed pole pieces to produce a design both smaller and lighter than other arrays of equivalent magnetic field strength. Because magnets may be custom engineered to specific requirements, user is not restricted to stock magnet types, thereby providing greater latitude in parameters for focusing arrays. Pole pieces may also be provided according to specification, with the added assurance that, because of special Kearfott design techniques, B axial magnetic fields approximately 10% higher than those generally obtained in standard types may be produced.

TYPICAL CHARACTERISTICS

Peak Magnetic Field Strength	1200 gauss
Period	0.560 in.
Length	5.64 in.
Inside Diameter of Pole Pieces	0.400 in.
Outside Diameter	2.0 in.
Weight	3.2 pounds

Write for complete data.

BASIC BUILDING BLOCKS FROM KEARFOTT

INTEGRATING TACHOMETERS

Kearfott integrating tachometers, special types of rate generators, are almost invariably provided integrally coupled to a motor. They feature tachometer generators of high output-to-null ratio and are temperature stabilized or compensated for highest accuracy integration and rate computation. Linearity of these compact, lightweight tachometers ranges as low as .01% and is usually better than ± .1%.

TYPICAL CHARACTERISTICS

	Size 11 (R860)
Excitation Voltage (400 cps)	115
Volts at 0 rpm (RMS)	.020
Volts at 1000 rpm (RMS)	2.75
Phase shift at 3600 rpm	0°
Linearity at 0-3600 rpm	.07
Operating Temperature Range	−54° +125°

Write for complete data.

Miniature Floated Gyro

Precise Angle Indicator

20 Second Synchro

KEARFOTT DIVISION
GENERAL PRECISION INC.
LITTLE FALLS, NEW JERSEY

Midwest Office: 23 W. Calendar Ave., La Grange, Ill.
South Central Office: 6211 Denton Drive, Dallas, Texas
West Coast Office: 253 N. Vinedo Avenue, Pasadena, Calif.

Engineers: Kearfott offers challenging opportunities in advanced component and system development.

How RECOMP handles numbers that could circle the world 2½ times

RECOMP can handle a floating point number greater than four billion factorial... or larger than the figure 1 followed by 41 billion zeros. Typewritten, the number would stretch around the world two-and-one-half times.

RECOMP is a low-cost, general purpose, digital computer—the original solid state computer with *proven reliability*. Its built-in floating point arithmetic and square root instructions come as a standard feature among RECOMP's 49 commands... at no extra cost.

Easy to operate, easy to program... RECOMP has a storage capacity of over 8000 instructions, simplified coding, fingertip control console with digital readout panel, and a high-speed photoelectric tape reader.

High-powered RECOMP is designed to solve problems of engineering, science, and industry. For information on how RECOMP can solve your special problems, write Autonetics Industrial Products Division, Dept. 304, 3584 Wilshire Boulevard, Los Angeles 5, California.

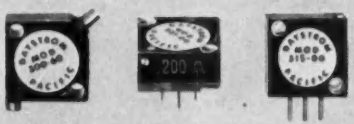
Digital computers by Autonetics

INDUSTRIAL PRODUCTS

A DIVISION OF NORTH AMERICAN AVIATION, INC. Other offices: Chicago, New York, Washington, D.C.

A complete, flexible product line of reliable, precision subminiature potentiometers from DAYSTROM

More than 32 basic models . . . many exclusive and unique features . . . over 252 variations for military and industrial use.



Series 300 Series 301 Series 315

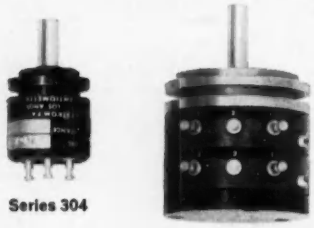
FULL SIZE—U.S. PATENT 2,880,293

SQUARETRIM POTENTIOMETERS

"the world's smallest trimmers"

for high resolution, minimum space requirements in airborne, missile, and ground instruments and systems applications where stability is a vital requirement.

These tiny SQUARETRIM models have an exclusive square shape for optimum packaging that allows stacking as many as twenty units into one cubic inch. Other features: more accurate trimming—almost one-third more turns per sweep than conventional models . . . greater stability through an exclusive worm gear adjusting device and the unique circular design of the mandrel.



Series 304 Series 319 (2 gang)

FULL SIZE—PATENTS PENDING

SINGLE-TURN POTENTIOMETERS

highest quality potentiometers, designed for exceptional linearity and maximum reliability and accuracy in applications where space is at a premium.

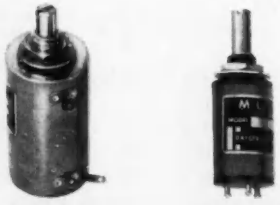
These series are small, compact, highly precise potentiometers. Typical examples: Series 304 utilize precision winding techniques that give linearity from 0.3% to 3%; a design that provides at least a 500,000 cycle service life. High temperature Series 314 (−55°C to +250°C) meets or exceeds latest environmental military specifications. Series 319 can be ganged without the use of bulky clamp rings . . . with each wiper positioned independently to meet any phasing need.

FULL SIZE—U.S. PATENT 2,856,493

MULTI-TURN HIGH PRECISION POTENTIOMETERS

for rigorous temperature, altitude and vibration requirements in aircraft and missile applications.

Smallest package of its type, the Series 341 meets the most exacting performance requirements and is built to withstand severe vibrations or shock, eliminate backlash and reduce phase shift to negligibility. Standard models are ten-turn; models also available in 3 and 5 turns.



Series 410 Series 450

HALF SIZE—U.S. PATENT 2,900,614

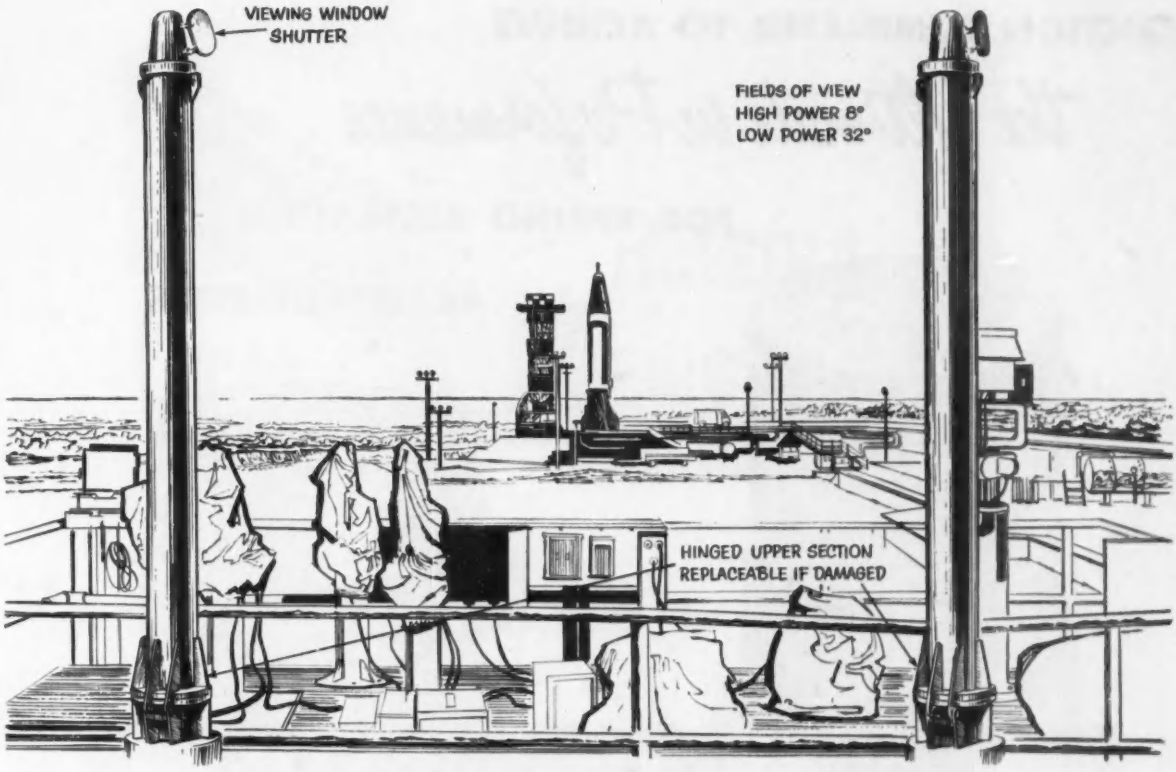
MULTIPOT® POTENTIOMETERS

for low-cost requirements in general test equipment and computer applications.

All the MULTIPOT potentiometers provide a high degree of reliability and accuracy without the penalty of premium price. Precision winding techniques ensure exceptional resolution and desirable performance characteristics in a small, efficient package.

For complete specifications write for Data File CE-880-1.

DAYSTROM, INCORPORATED
PACIFIC DIVISION
9320 Lincoln Boulevard, Los Angeles 45, Calif.



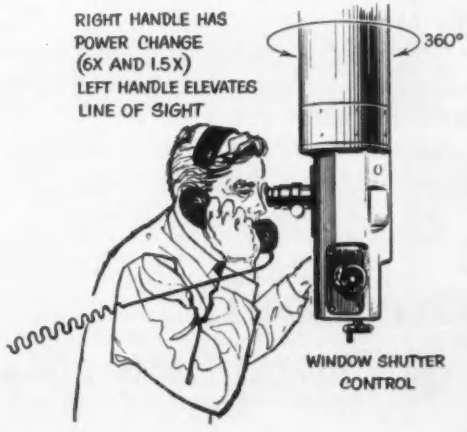
Cape Canaveral count-downs get Kollmorgen close-ups

What happens on the pads at Cape Canaveral is subject to the continuous close scrutiny of experts thanks to Kollmorgen bunkerscopes. During launching operations and static tests the trained observer sees exact detail in his choice of two magnifications and in true color, with complete safety even in cases of power failure.

Bunkerscopes by Kollmorgen require virtually no maintenance and are built to withstand blast forces such as may be expected around missile launching sites. They are easy to operate, even by untrained personnel, and can quickly be adapted to photography and television use.

These instruments are typical of Kollmorgen experience with remote viewing and inspection equipment, wall periscopes, underwater periscopes, micro-photo periscopes, continuous strip fuel-inspection cameras and other optical systems employing mechanical and electronic skills. In this field Kollmorgen is foremost, having served both industry and defense for nearly half a century.

If you are interested we would like to send you our new illustrated facilities brochure. Just write us a note on your company letterhead.



KOLLMORGEN
optical corporation
NORTHAMPTON, MASSACHUSETTS

NUCLEAR REMOTE VIEWING EQUIPMENT • SUBMARINE PERISCOPES • OPTICS • BORESCOPES • MOTION PICTURE AND TELEVISION LENSES • PRECISION OPTICAL INSPECTION AND ALIGNMENT DEVICES • ELECTRONIC CONTROLS AND COMPONENTS • NAVIGATIONAL AIDS

WESTERN TECHNICAL REPRESENTATIVES –
COSTELLO & COMPANY, LOS ANGELES, CALIFORNIA.

FRICTION ELIMINATED TO ACHIEVE

the Ultimate in Performance

FOR SPRING RESTRAINED ACCELEROMETERS

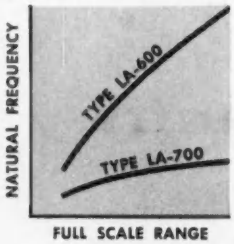
TYPE LA-600
shown actual size

- Full Scale Range: ±1 to ±40 G
- Full Scale Output: to 25 volts
- Threshold-Resolution: 0.0001 G
- Damping Ratio: 0.6 ±.2 typical from −65°F to +250°F
- Natural Frequency: 16 to 100 cps
- Cross-Axis Sensitivity: 0.005 G per G maximum
- Shock: to 60 G
- Vibration: 10 G to 2000 cps
- Size: 1⅞" diameter, 2⅜" long
- Weight: 1.2 lbs. maximum

TYPE LA-700
shown actual size

- Full Scale Range: ±1 to ±60 G
- Full Scale Output: to 25 volts
- Threshold-Resolution: 0.0001 G
- Damping Ratio: 0.6 at 25°C typical
- Natural Frequency: 5 to 30 cps
- Cross-Axis Sensitivity: 0.005 G per G maximum
- Shock: to 100 G
- Vibration: 15 G to 2000 cps
- Size: 2½2" diameter, 2⁷⁄₁₆" long
- Weight: 1.2 lbs. maximum

The virtual elimination of friction in both these new Honeywell linear accelerometers is made possible by a unique web spring suspension. This feature combined with an electro-magnetic pick-off permits resolutions of extremely low level inputs.



These two instruments span the entire range of dynamic performance.

The LA-600 with its magnetic damping is used for higher natural frequency applications. The LA-700 with its compensated fluid damping is designed for lower natural frequency applications. Write for Bulletins LA-600 and LA-700 to Minneapolis-Honeywell, Boston Division, Dept. 34, 40 Life Street, Boston 35, Mass.

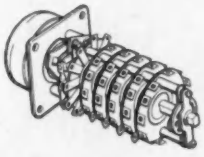
75th YEAR PIONEERING THE FUTURE

Honeywell

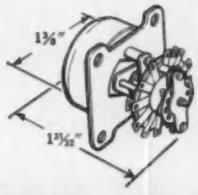
H HONEYWELL SINCE 1885 *Military Products Group*

Ledex Rotary Selector Switch

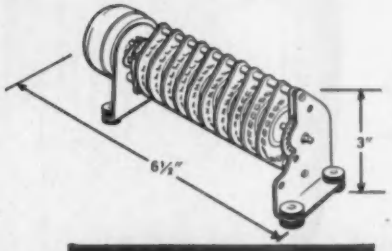
BASIC INFORMATION



Functions as a power operated remote control circuit selector or stepping switch.

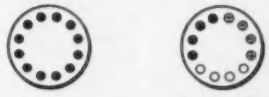


Smallest switch is size 2E with 1 to 4 wafers.



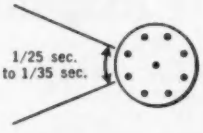
Largest standard switch is size 5S with 1 to 10 switch wafers. Foot, flange or panel mounting.

Switch wafers available with 8, 10, 12, 18, 20 or 24 positions.

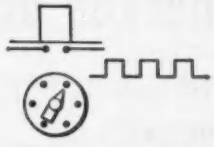


Circuitry of wafers is flexible. For example 12 position wafer can be one circuit with 12 positions or 3 circuits with 4 positions each.

Will not stop in non pre-selected position.



Self-stepping speed is 25 to 35 steps per second depending on number of positions.



Pushbutton, manual rotary switch, or pulse controlled.

Hermetically sealed switches meet extreme environmental conditions.

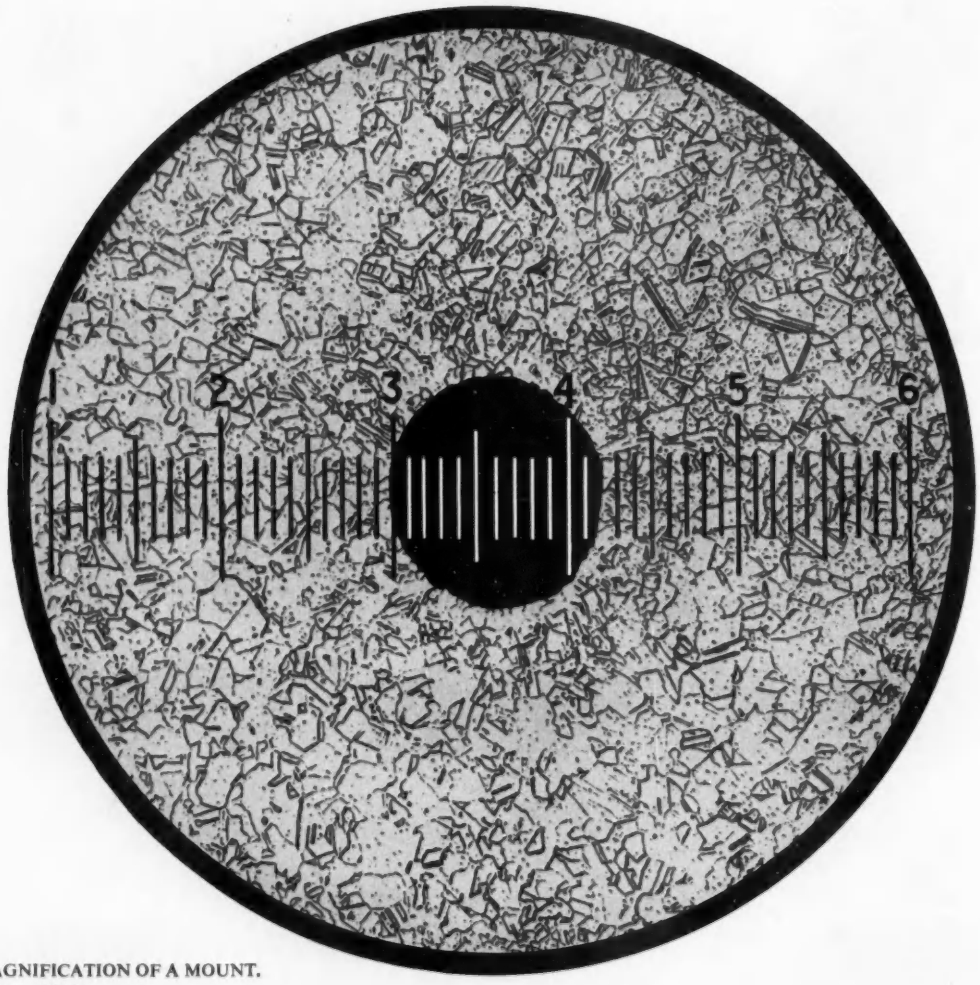
The Ledex Rotary Selector Switch is a compact, highly efficient power-operated circuit selector or stepping switch, designed for remote control. Nearly unlimited design combinations permit great variety of applications for stepping, counting, adding, subtracting, programming and sequencing. Many stock models on hand for immediate shipment. Hermetically sealed models also available.

Power source is the Ledex Rotary Solenoid. This unit gives highest-torque-to-size rotary motion. Applications for Rotary Solenoids include actuation of valves, vanes, shafts, and other mechanical loads.

Also Ledex Syncramental Stepping Motors for accurate, reliable shaft indexing.

Write for literature, mentioning application, to Ledex, Inc., Dayton 2, Ohio; Marsland Engineering, Ltd., Kitchener, Ont.; NSF Ltd., 31 Alfred Place, London, Eng.; NSF GmbH, Nurnberg, Germany.

LEDEX



100X MAGNIFICATION OF A MOUNT.
Each division .001 in.

Capillary ID size is checked under 100x magnification

—yet this critical inspection is only 1 of 3 used to check ID of Superior capillary tubing

At Superior, in checking the ID size of capillary tubing we don't rely on only one reading from our inspection microscope, we require four. Then we double-check in two other ways—one the use of a relatively simple plug gage, the other a comprehensive flow inspection to ascertain the average ID dimension. These inspections also give you assurance of a free passage through the bore, uniformity of ID surface and a satisfactory grain structure.

Superior has spent years in the development of manufacturing processes and quality control procedures for the production of close tolerance capillary tubing. ODs range up to 3/16 in., IDs from .004 through .040 in. Analyses include Types 304, 316, 321, 347 and 446 stainless; also Monel, Inconel, nickel and carbon steel alloys. Data Memorandum No. 11 gives complete details—let us send you a copy. Superior Tube Company, 2026 Germantown Ave., Norristown, Pa.

Superior Tube
The big name in small tubing
NORRISTOWN, PA.

All analyses .010 in. to 5/8 in. OD—certain analyses in light walls up to 2½ in. OD

West Coast: Pacific Tube Company, Los Angeles, California • FIRST STEEL TUBE MILL IN THE WEST

AMPLISOLVER*

*American Electronics' new Amplifier/Resolver module

GREATER STABILITY IN A SMALLER PACKAGE!

AMPLISOLVER is a compact package only 3 inches long, with a Size 8 winding compensated resolver and a dual channel buffer amplifier, within a Size 15 frame. AMPLISOLVER offers unity transformation ratio with Zero phase shift, over a temperature range from —55°C to +125°C.

AMPLISOLVER is the lightest module of such accuracy in the industry, weighing only 8 oz. The unit features an input impedance of 1 megohm minimum with a low output impedance of 270 + j400 ohms. Direct drive from resolver to amplifier eliminates the cable connections. Trim adjustment on AMPLISOLVER can be made in the field to ± 2% of unity transformation ratio of 1 to 1. Its versatile design features permit adapting AMPLISOLVER to computing resolver chain functions.

SPECIFICATIONS—MODEL 15RA5E-11D

Input Voltage	10
Amplifier Power Supply (Volts D.C.) (Reg.)	30 ± .3
Input Impedance	1 megohm min.
Output Impedance (ohms)	270 + j400
Maximum Null Voltage (volts)	
Fundamental	.010
Total	.015
Maximum Functional Error (%)	0.1
Transformation Ratio (Rotor/Input)	1.000 ± .001
Phase Shift (Degrees)	0 ± 0.1
Meets MIL SPEC MIL-E-5272C	

For complete information write:

AMERICAN ELECTRONICS, INC.

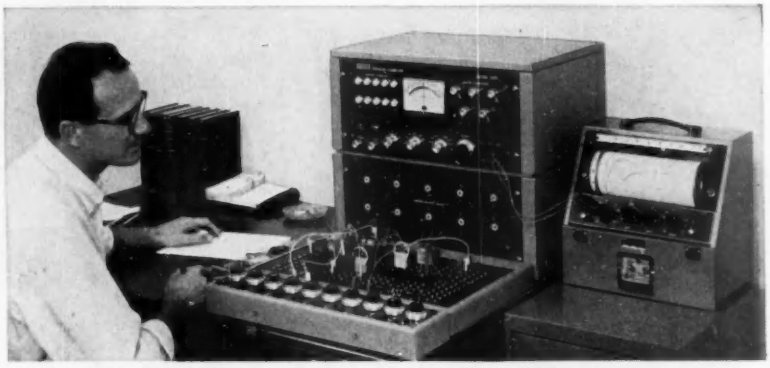
INSTRUMENT DIVISION

9503 WEST JEFFERSON BOULEVARD, CULVER CITY, CALIFORNIA

What you should know about Analog Computers

Judging from the literature, most discussion of analog computers turns on form rather than function.

Every computer manufacturer, including Donner, is ready to tell you all about their designs, right down to the last microvolt. Few spend their literary effort in telling you how to use them and what kind of problems are amenable to analog computer solution. Not too strangely, this is what you, the prospective user, wanted to find out in the first place.



The Donner 3400 Desk-top Computer functions as a compact, versatile electrical model of a dynamic system.

HOW AN ELECTRONIC ANALOG COMPUTER SOLVES PROBLEMS

A mathematical expression which defines the dynamic behavior of a particular physical system also describes the behavior of all other analogous systems. A general purpose analog computer can be programmed to behave as one of these analogous systems. So programmed, it can be used to explore the characteristics of the system or to "solve" the describing equations. Typical problems range all the way from explaining the laws of classical and modern physics to the physiological relations of life itself. Here are some of the fields where analog computers are in use: antenna design, medical research, cybernetics, electron trajectories, nuclear reactor design, fluid mechanics, heat transfer analysis, aerodynamics, meteorology, classical and nuclear physics, chemical kinetics, petroleum, engineering, servo system analysis, auto- and cross-correlation, and economic forecasting.

Assembly of Donner 3100 series high accuracy medium size analog computers in quantity lots provides the user with more value at lower cost. Complete Donner 3100 Computer Consoles start at just under $11,000.

Basic computing elements in an electronic analog computer are dc amplifiers, precision components (resistors, capacitors, and potentiometers), and non-linear accessories (multipliers, function generators, and transport delay simulators).

By interconnecting the computing elements at a patchboard, varying voltage amplitudes can be integrated, summed, differentiated, multiplied, divided, altered in non-linear fashion, and otherwise operated on as directed by a mathematical equation. The answer, which appears as a varying voltage, can be visually observed on a voltmeter or an oscilloscope and permanently recorded by any one of several plotting devices.

The analog computer user can take an equation, change the coefficients at will, and get whole sets of solutions with amazing ease and speed. He can get these results to accuracies of 0.1% or better for a very modest investment. Small Donner computers begin at just over $1,000.

ANALOG OR DIGITAL

The chief advantages of the analog technique are speed, economy, and flexibility. With the analog computer, you get a genuine insight into the response of the system to both internal and external stimuli. No other approach can bring the investigator into such intimate contact with the system.

Digital computers sometimes provide more accurate results, but they seldom give the user the same knowledge because they are at best only machines that compound arithmetic information. Unlike digital computers, analog computers actually behave just like the simulated systems.

TWO NEW PUBLICATIONS PROVIDE MORE INFORMATION

If you are interested in learning more about the application of analog computers, copies of Donner Tech Notes #1 and #2 are available from your nearby Donner engineering representative or directly from the factory. Tech Note #1 is titled "How to Simulate a Non-Linear Control System with an Analog Computer;" Tech Note #2, "How to Use and Program Analog Computers."

Donner Scientific specializes in the manufacture of accurate fixed and general purpose analog systems designed to analyze, measure, and control dynamic inputs. Complete technical information and informed applications assistance can be obtained from your nearby Donner engineering representative or writing Dept. 084.

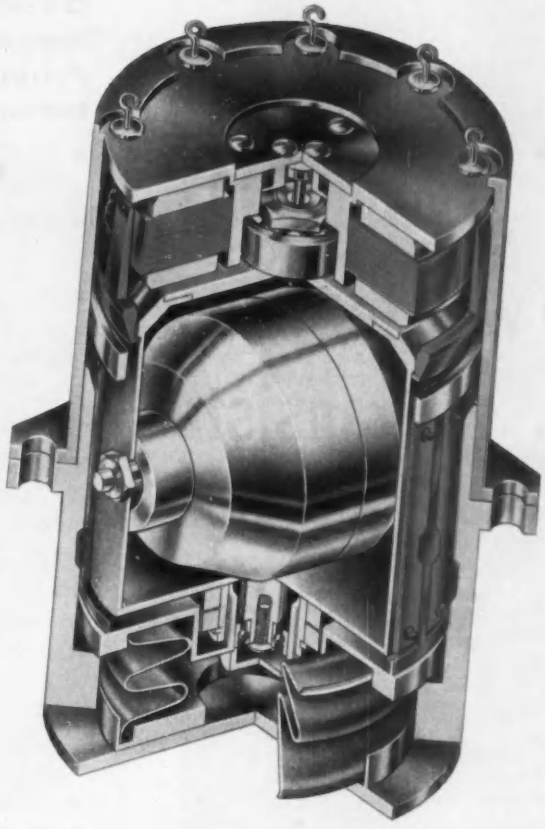
DONNER SCIENTIFIC COMPANY

888 Galindo • CONCORD, CALIFORNIA
Phone: MUlberry 2-6161

24

Ketay 2″ floated rate gyro controls damping from −54° to +74° C.

... saves space, weight, wattage and wear



Ketay has been successful in developing a floated rate gyroscope with a unique bellows and spring fingers system which compensates for temperature changes. Fluid viscosity is allowed to change freely, while the damping gap is controlled instead. This ingenious shear damping principle offers true "second order performance." No heating is required from −40° to + 74° C.

THIS UNIQUE KETAY FLOATED DESIGN FOR TELEMETERING AND INSTRUMENTATION OFFERS:

- increased shock (150G) and vibration (25G) resistance.
- gimbal support on precision ball bearings and support independent of torsion bars, permitting gimbal balance to exceptional accuracies.
- DC motor with direct battery operation, resulting in rapid run-up.
- AC motor without brushes, achieving longer life.
- AC or DC pick-offs. AC units give high output: 7½ volts per degree of gimbal deflection.
- 200 turn wire wound potentiometer

TYPICAL RG 20 SPECIFICATIONS

Rate (deg/sec)	±30
Natural Frequency	25 cps (min)
Size	Diameter 2″ Length 2⅛″
Damping (Ratio to Critical) over temperature	.07 ±0.2
Spin Motor	115V Line to Line 3φ 400 cps
Pickoff Type	Inductive
Excitation	26 VRMS 400 cps
Sensitivity (v/deg/sec)	0.2
Threshold (deg/sec)	0.06
Weight	1¼ lbs. (max)

For detailed specifications and drawings write to:

KETAY DEPARTMENT

NORDEN
DIVISION OF UNITED AIRCRAFT CORPORATION
Commack, Long Island, New York

CIRCLE 85 ON READER SERVICE CARD 85

FOUND:

a way to reduce transistor inspection costs 50% or more

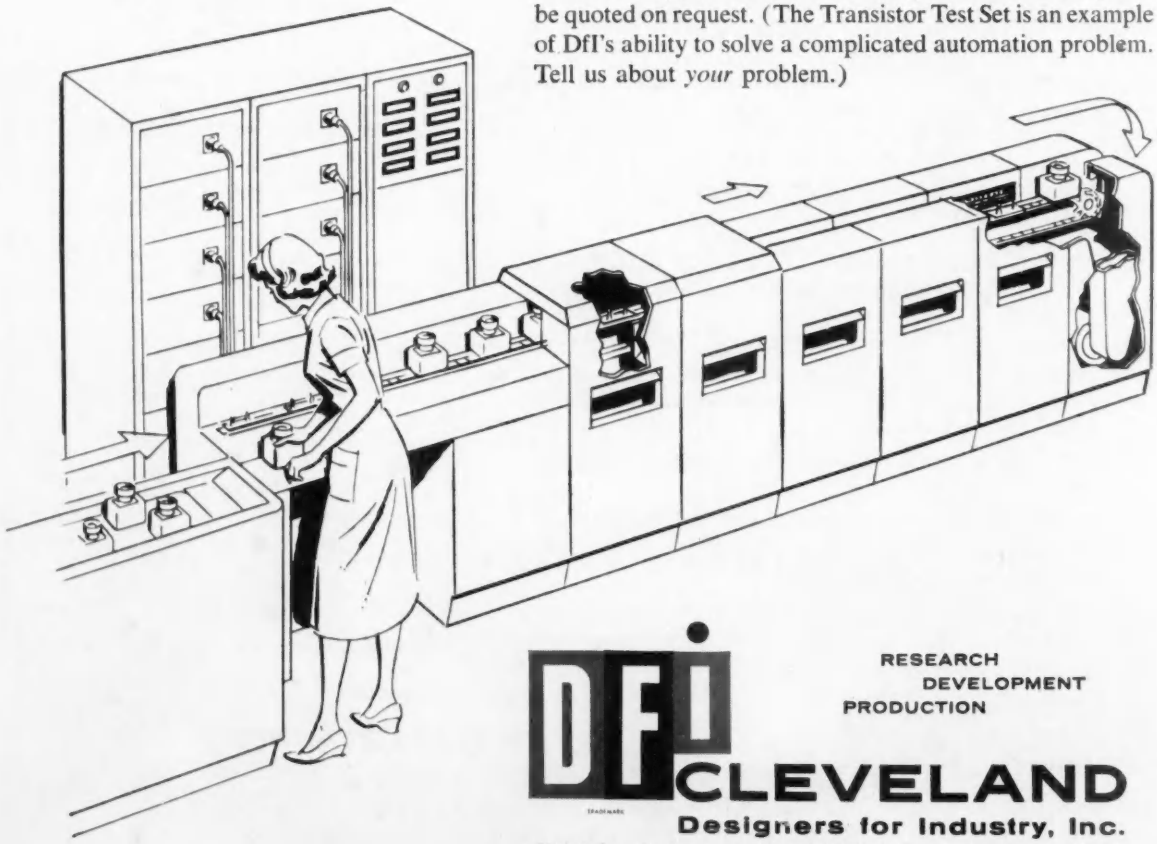
DfI–Cleveland's Automatic Transistor Test Set eliminates manual inspection. Promised: a major reduction in manufacturing cost.

- Automatically tests, rejects and classifies at 2400 units/hr. maximum rate.
- Performs as many as 38 tests—all required parameters.
- Master card programming permits instant set-up for every transistor type.
- Unitized design provides optimum flexibility to meet present and future requirements.
- Design concept is applicable to diodes, capacitors, resistors.

Name your parameters, and the unit performs all tests automatically—orientation, short circuits, 15 d-c tests, 21 a-c tests and 4 optional environmental tests.

Tests at each of 14 stations can be programmed separately, and in correct relation to each other. Then, master cards can be used to program complete inspection and sorting of every transistor type you make. All tests are self-checking. Stations are unitized, permitting easy modifications, additions or deletions. The entire unit should amortize within six months.

Write for product bulletin. Firm prices and delivery will be quoted on request. (The Transistor Test Set is an example of DfI's ability to solve a complicated automation problem. Tell us about *your* problem.)



RESEARCH
DEVELOPMENT
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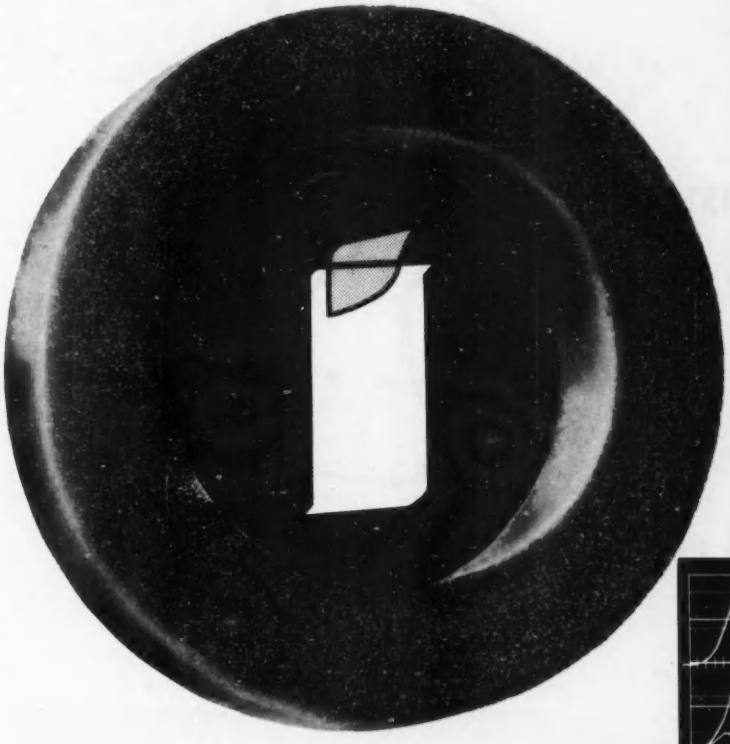
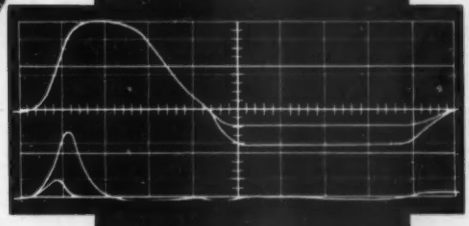
Now...one microsecond



Complete Core Memory Cycle with TMI Word-Select Technique

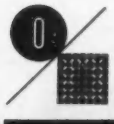


TMI pioneers again to make commercially available a newly developed advanced core memory product. Type LQ memory products provide a complete **clear/write** and **read/restore** memory cycle at rates to one megacycle, utilizing a new word-select design technique. These products are offered by Telemeter Magnetics in any form desired—from cores to complete memory systems.

Cores For those memory manufacturers who prefer to wire their own arrays, TMI word-select ferrite cores may be ordered now. These high speed cores provide extremely fast switching with low drive current.

Arrays and Stacks You may take advantage of the skill and production efficiency developed at TMI in manufacturing millions of cores, most of which have been assembled into arrays and memory stacks. This know-how is being applied to assembly of the new word-select cores into configurations to meet virtually any high speed computer design need.

Memories A new ultra-speed memory—the Type LQ—is available for commercial delivery in late 1960. Operating speeds up to 1.0 microsecond random access cycle time are now economical and result from the development of special ferrite cores and advanced driving and sensing circuits. The LQ word-select memory permits application to a wide variety of speed and capacity requirements.



TELEMETER MAGNETICS Inc

P.O. Box 329, Culver City, California
Data Equipment Division, 9937 Jefferson Blvd., Culver City, Calif.
® Components Division, 2245 Pontius Ave., Los Angeles, Calif.

For complete specifications or to discuss your problem with a TMI applications engineer write or call

PIONEERS IN DEVELOPMENT AND MANUFACTURE OF CORE MEMORY PRODUCTS

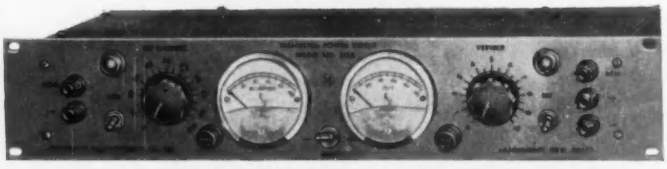
A 1-WATT RESISTOR BECOMES A VOLTAGE STANDARD WHEN USED WITH A ®REGATRON PROGRAMMABLE POWER SUPPLY

Take a 1-watt resistor. Place it across the programming terminals of a Regatron Programmable Power Supply. Instantly you've fixed the output voltage to 1/1000 of the resistance value. For example, a 22.5K resistor will fix the output at 22.5V. For a perfect repeat every time, use the same resistor. For other voltages use a different resistor. The output will always equal 1/1000 of the resistance value.

In addition, you'll find that Regatron Programmable Power Supplies have all the other advanced features you would expect in a versatile laboratory instrument; superregulation, vernier as well as main voltage control, and more. Compare a Regatron Programmable Power Supply with any other d-c power source, batteries included. You'll find you won't settle for less.

Regatron Programmable Power Supplies are available in voltage ranges covering 0-50 V dc, 0-100 V dc, 0-300 V dc, and 0-600 V dc. Current ratings are up to 3A, depending on model. Request Bulletins 350 and 765.

(Various models without the programming feature are also available in voltage ranges up to 1000 V and currents up to 1 ampere.)



TRANSISTOR TYPES

MODEL NUMBER	OUTPUT		REGULATION				MAXIMUM RIPPLE IN MV
			LINE 105—125 V AC 50—60 CPS		NO LOAD TO FULL LOAD		
	Voltage	Current	%	V	%	V	
212A[1]	0—100 V DC	0—100 MA	0.15	0.05	0.1	0.05	½
2-212A[1]	EQUIVALENT TO TWO MODEL 212A's. OUTPUTS MAY BE USED IN SERIES, PARALLEL, OR INDEPENDENTLY.						
224A[1]	0—100 V DC	0—200 MA	0.15	0.05	0.1	0.05	1
220A	0—50 V DC	0—500 MA	0.1	0.05	0.1	0.05	1
221A	0—100 V DC	0—500 MA	0.1	0.05	0.1	0.05	1
213A	0—50 V DC	0—1 AMP	0.1	0.05	0.1	0.05	1
214A	0—100 V DC	0—1 AMP	0.1	0.05	0.1	0.05	1
215A	0—50 V DC	0—3 AMP	0.1	0.05	0.1	0.05	1
218A	0—100 V DC	0—3 AMP	0.1	0.05	0.1	0.05	1

1. Modulation input provided for measurement of transistor parameters by small signal method.

® REGISTERED U.S. PATENT OFFICE. PATENTS ISSUED AND PENDING.

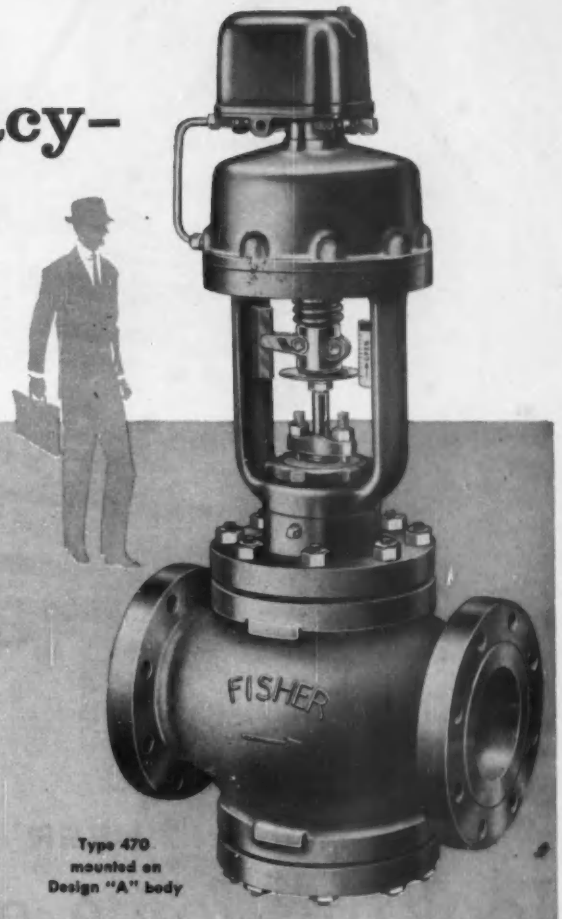
ELECTRONIC MEASUREMENTS COMPANY, INCORPORATED

EATONTOWN • NEW JERSEY

YOUR **FISHER/MAN** STANDS BEHIND THIS PNEUMATICALLY OPERATED PISTON...

FOR Inherent Accuracy–Power–Speed and Stability

FISHER TYPE 470 P.O.P.



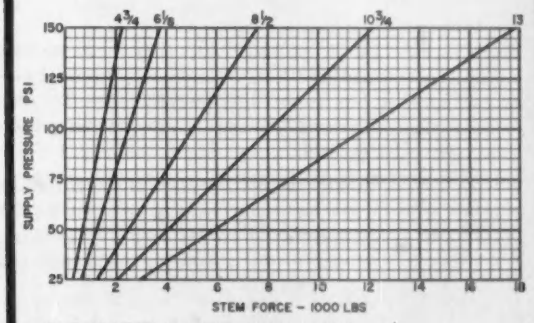
Type 470 mounted on Design "A" body

- **Delivers same power in either direction at any point of the stroke.**
- **Adaptable to virtually all types of valve bodies including Butterfly valves.**
- **No air set required—utilizes clean, non-corrosive air or gas up to 150 psi.**
- **Easily reversible actuator can be changed in the field.**

This small, compact piston actuator incorporates its own positioner mounted integrally on top of the cylinder. Positioner receives any of the normally used pneumatic instrument signals. Then, without an air set, actuator utilizes the full potential of the available instrument or gas supply to provide exceptional speed and power. Series 470 is available in six basic sizes and can be supplied for travel up to 4". Basic actuator can also be furnished with a handjack, hydraulic snubber, pneumatic safety devices or as a spring return unit. Write for Bulletin E-470.

PERFORMANCE DATA

Air Consumption (Static)	20 SCFH at 100 psi supply.
Instrument Signals	3 to 15 psi, 5 to 25 psi, 6 to 30 psi, 12 to 60 psi. Suitable for split range also.
Temperature Limitation	175°F.
Maximum Hysteresis	0.15% of total stroke or instrument signal.
Repeatability	0.03% of the total stroke or instrument signal.
Resolution Sensitivity	Minimum change in the measured variable to produce an effective movement of the final control element is .02% of the instrument pressure range.
Frequency Response	1.4 cps for the Size 60. 4 cps for the Size 30.
Load Sensitivity	Percent of total travel per 100 lbs. stem force is .065% for Size 60.



CYLINDER DIAMETERS AS MARKED ON EACH CURVE.

AVAILABLE STEM FORCE

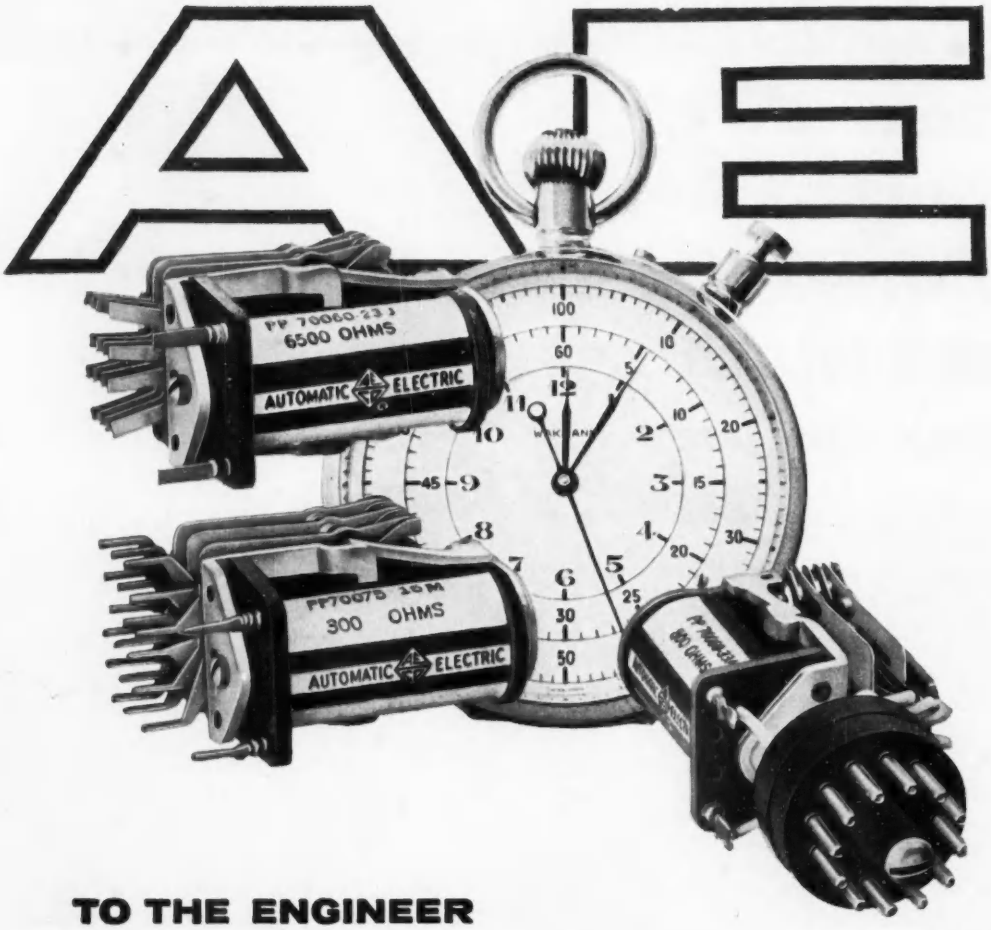
IF IT FLOWS THROUGH PIPE ANYWHERE IN THE WORLD...CHANCES ARE IT'S CONTROLLED BY...

FISHER GOVERNOR COMPANY

Marshalltown, Iowa / Woodstock, Ontario / London, England

BUTTERFLY VALVE DIVISION: CONTINENTAL EQUIPMENT COMPANY, CORAOPOLIS, PA.

FISHER Controls SINCE 1880



TO THE ENGINEER

looking for a quick connection

Engineers out to cut costs at no expense of reliability can count on dramatic savings in assembly and wiring time by designing around AE Class E relays with quick-connect terminals.

Series EQPC is designed for direct insertion into printed circuits. Series EQTT, with Taper-Tab terminals, provides firm, high-conductivity connections without soldering.

AE also supplies Class E relays prewired for plug-in – with standard 8- to 20-prong octal plugs. Where additional relay protection is essential, the plug-in types are available in hermetically sealed containers or with dust-tight housings and hold-down brackets.

The AE Class E relay is a miniaturized version of the premium-quality Class B, with many of its best features. Perfect contact reliability exceeding 200 million operations is common.

AE is also equipped to supply wired and assembled, custom-built control units, *or to help you develop complete systems.*

Want details? Just write the Director, Control Equipment Sales, Automatic Electric, Northlake, Illinois. Also ask for Circular 1702-E on *Relays for Industry*, and the new 32-page booklet on *Basic Circuits.*

AE CAN DO

AUTOMATIC ELECTRIC GENERAL SYSTEM

Subsidiary of

GENERAL TELEPHONE & ELECTRONICS

CIRCLE 90 ON READER SERVICE CARD

CIRCLE 91 ON READER SERVICE CARD

WARNER'S new miniature electric brakes and clutches

give you direct automatic actuation

Take advantage of *direct* automatic actuation for aircraft components, computers, and similar low-torque instrument drives!

Warner's miniature RF-80 electric brakes and SF-80 clutches use simple control circuitry for instant actuation, automatic indexing, smooth inching and jogging, rapid cycling, accurate synchronization, and positive engagement of torque loads up to 1.5 lb-in.

Electromagnetic principle permits stepless torque modulation, automatic operation, and remote actuation from various standard controls. D-c voltage is adjusted easily for cushioned or abrupt couples or stops.

Compact design (approximately 1" dia. x ⅞" length) provides high torque per inch while controlling complex mechanical movements in limited space. Two-piece floating armature avoids complex alignments during assembly.

Operate instantly in any position of rotation . . . no notches, teeth, or lugs to match up. Used for accurate indexing or linear positioning without positive stops.

See the speed, adjustability, and control-*ability* of Warner miniature electric brakes and clutches on your own desk top! Your Warner representative has a plug-in demonstrator that simulates a variety of start, stop, inching, jogging, or torque-adjustment applications. Phone him today, or ask us to arrange an appointment.

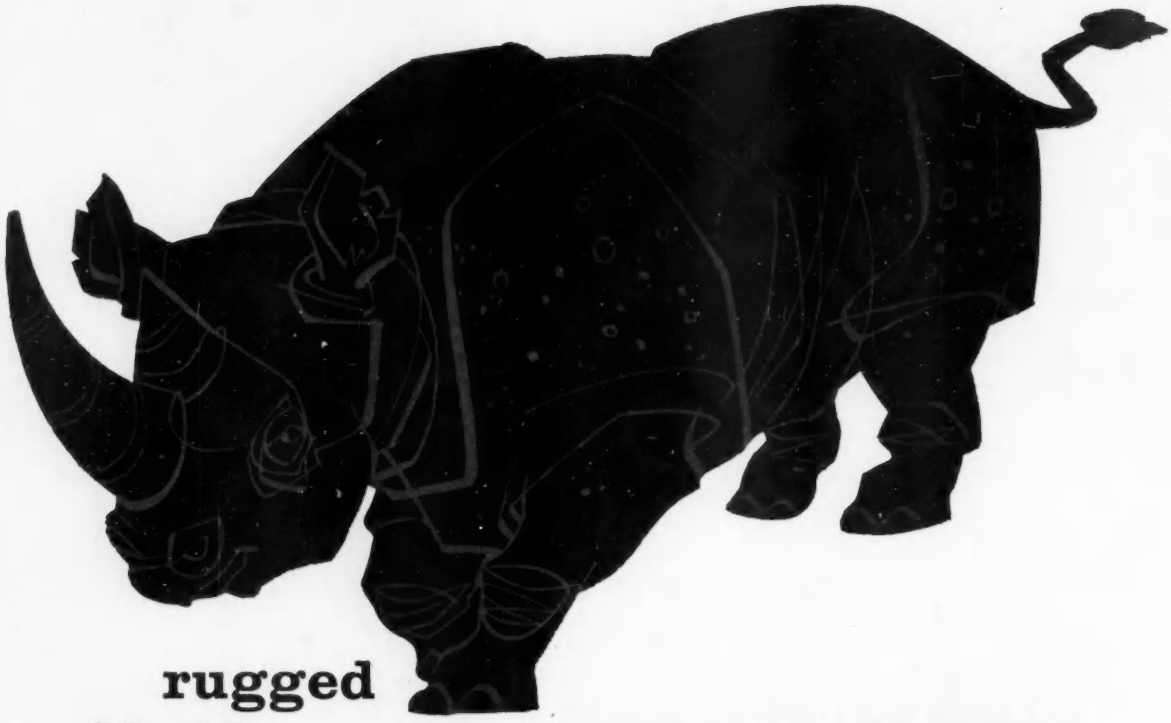
originators of electric motion control

Warner Electric Brake & Clutch Co.

WARNER

Beloit, Wisconsin

Complete line—from 1.5 lb.-in. to 700 lb.-ft.



rugged North "Rhino" relays

(Ruggedized Hermetically Inclosed)

4 AND 6 POLE GENERAL PURPOSE TYPES

If you need relays to perform under environmental extremes, North 4 and 6 Pole Hermetically Sealed Subminiatures have high shock and vibration resistance, and give you superior performance and maximum reliability. They are highly adaptable to missile and airborne applications as well as other critical military and commercial uses. Designed for the stringent specifications of MIL-R-5757A, B, C and MIL-R-25018 (USAF), these relays are available in plug-in types in 4 and 6 pole units, AC, DC and Dry Circuit.

- Precision balanced rotary motors.
- Stepped headers for ease of wiring and inspection.
- Simultaneous switching of full rated loads and dry circuits.
- Special contact ratings for special purposes.
- Contain "Getters" for absorption of organic vapors to extend contact life.

For detailed information on North 4 and 6 Pole Hermetically Sealed Subminiature Relays, write

ELECTRONETICS DIVISION

NORTH ELECTRIC COMPANY

614 S. MARKET ST., GALION, OHIO

60-C-3

ASCOP

NEW

13 BIT ALL-MAGNETIC Shaft-Position Digital ENCODER

In any environment, in all applications, ASCOP magnetic encoders have proved to be rugged and tough. Our customers say that nothing compares to them for endurance and perfect performance under the worst conditions.

Now ASCOP has taken the same unique magnetic readout principle and incorporated it into a neatly miniature, ruggedly simple design to read out shaft positions to one part in 2^{13}. Parallel output is in binary code and total count is reached after 64 turns of the precision shaft and gearing. Lead-lag head arrangements assure that external decision making circuitry is minimized. The new ASCOP encoder operates in either direction and can be read out at rest or on-the-fly at speeds up to 10,000 rpm with equal facility. Since the only contacting parts are shaft and gearing, these are the only factors affecting life.

Condensed Specifications

Total Count: 2^{13} achieved in 64 turns of input shaft
Size: ..... 2¼" dia. x 3⅛"
Code: ..... Binary with lead-lag heads
Output: ..... Parallel
Weight: ..... 16 ozs.
Inertia: ..... 70 gm-cm²
Breakaway Torque: ..... 0.05 in. oz.
Max. RPM: ..... 10,000 rpm
Expected Life: 20,000 hrs. at 4000 rpm (expected bearing and gear life)

Brochure, price and applications notes on request

ASCOP a division of **ELECTRO-MECHANICAL RESEARCH, INC.**
P.O. BOX 44 • PRINCETON, NEW JERSEY

CIRCLE 93 ON READER SERVICE CARD 93

NEW! Meter Recorder Marking System with a Slip-In Cartridge!

Esterbrook's *customized* marking systems guarantee you complete satisfaction . . . for *any* type recorder . . . Circular, Strip, Miniature *or* Plotter!

Customized for your meter recorder by Esterbrook

Give your customers the big benefit of *ink cartridge convenience* and a century of applied experience in the recording product you manufacture!

Now—Esterbrook's Technical Products and Instrument Division will custom-design and build a new marking system for *your* product.

The result: no more breaking down . . . no more hand fixing . . . time and money saved! With Esterbrook's new *customized* meter marking system your customers will conserve operating time . . . *and* you'll receive the free design time and engineering assistance of experts!

For further information write to :

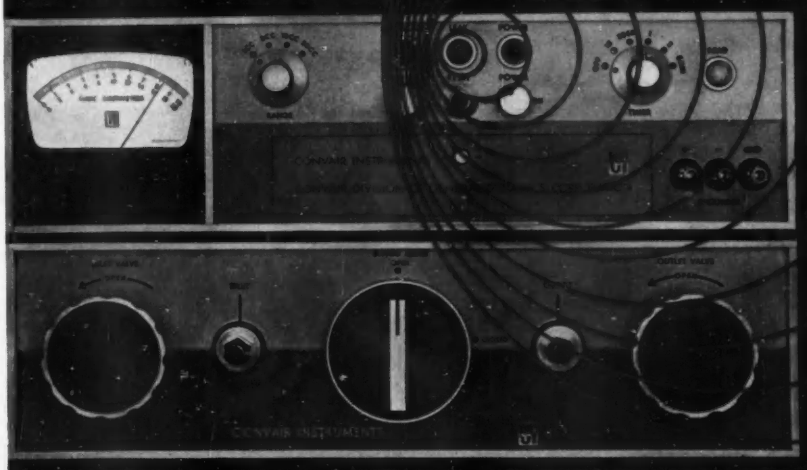
Technical Products and Instrument Division
The Esterbrook Pen Company • Camden 1, N. J.

TECHNICAL PRODUCTS AND INSTRUMENT DIVISION

The Esterbrook Pen Company

CAMDEN 1, NEW JERSEY

some leaks don't make drops



the all-new CI LEAKMETER doesn't depend upon catching drops in the measurement of hydraulic or fuel leakage!

The CI LEAKMETER, *when installed in a line between a pressure source and the system or component under test, automatically detects and signals the existence of a leak. It automatically measures and indicates the amount of the leakage. A red light signals the presence of a leak –the amount of leakage is indicated on an electrical meter. The* LEAKMETER *incorporates a timer which can be set for test durations of 15 seconds to 5 minutes, providing a range for the instrument of 0.008cc to 80cc per minute. To measure other rates of leakage, or to test for sustained zero leakage, the timer may be overridden and the test conducted for any desired period.*

The LEAKMETER consists of an Hydraulic Assembly and an Electrical Assembly. These may be installed together, or at separate locations in the test area. Both are designed for rack mounting. Hydraulic connections are made by quick-disconnect fittings.

The LEAKMETER is compatible with all common hydraulic fluids and fuels. The item under test may be subjected to shock, vibration, or temperature, from which the LEAKMETER remains isolated. The instrument accommodates pressures to 5000 psi. Jacks are provided for recording or other readout.

For Complete Information–or to purchase a LEAKMETER *for Immediate Delivery, Write, Wire, or Phone:*

CONVAIR INSTRUMENTS / CONVAIR, A DIVISION OF GENERAL DYNAMICS CORPORATION

3595 Frontier Street, San Diego, California
ACademy 3-1614

ELECTROMECHANICAL AND MECHANICAL INSTRUMENTS; AC AND DC MEASURING DEVICES, TRANSDUCERS.

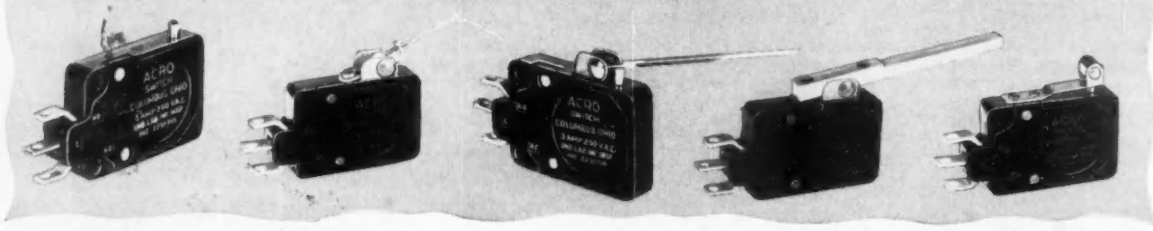
Does the miniature or sub-miniature switch you need have to function at minimum operating pressures? *Two Acro models meet your toughest electrical and mechanical requirements. Model Coin M operates on pressures as low as 2.5 grams; Model Z as low as 2 oz. pressure.*

These two dependable lines of Acro miniature and sub-miniature switches all feature Acro's famous rolling spring principle, and are available with a complete line of actuators. Most switches in these two series can be easily ganged for multi-pole applications.

Acro's Coin M switches, for instance, are only 9/32" thick and function perfectly wherever a precision, snap-action switch is required. Most common applications are in timers, control circuits, and vending machines.

Acro's model Z series — some so small they can hide behind a dime—features 24 types of actuators. All are built to conform to MS 25085 and Mil 6743. Gold-flashed contacts assure long shelf life.

model coin M switches — U.L. Approved — 3 Amp 250 V.A.C.



1CMD1-2AXX Basic Switch-Pin Plunger

Operating Characteristics

Operating force	20-27 gms.
Release force	12 gms. min.
Pretravel	.040 max.
Overtravel	.025 min.
Movement diff.	.030 max.

1CMD1-2AXX-A22 Wire Leaf Actuator

Operating Characteristics

Operating force	2.5 gms. max.
Movement diff.	.50" max.

1CMD1-2AXX-A24 Flat Leaf Actuator

Operating Characteristics

Operating force	2.5 gms. max.
Movement diff.	.50" max.

1CMD1-18AXX-A27 Nylon Leaf Actuator

Operating Characteristics

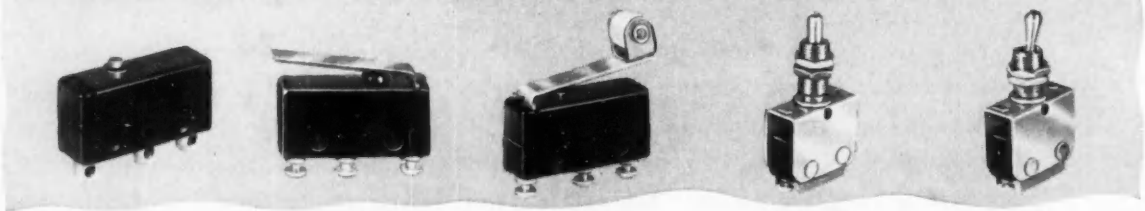
Operating force	6.0 gms. max.
Movement diff.	.30" max.

1CMD1-1AXX-A23M Roller Leaf Actuator

Operating Characteristics

Operating force	5-8 oz.
Release force	2 oz. min.
Pretravel	.040" max.
Overtravel	.025" min.
Movement diff.	.030" max.

model Z subminiature switches — U.L. Approved 5 Amp — 120-240 V.A.C.



ZD-0024 Standard Post Terminal

Operating Characteristics .010" Gap

Operating force	145 gms. max.
Release force	50 gms. min.
Movement diff.	.004" max.
Pretravel	.020" max.
Overtravel	.010" min.

ZLD-0035 Straight Leaf Actuator

Operating Characteristics .010" Gap

Operating force	2 oz. max.
Release force	½ oz. min.
Movement diff.	.015 max.
Pretravel	3/32 max.
Overtravel	.045 min.

ZLD-0033 Roller Leaf Actuator

Operating Characteristics .010" Gap

Operating force	2 oz. max.
Release force	½ oz. min.
Movement diff.	.015 max.
Pretravel	3/32 max.
Overtravel	.045 min.

ZPD-0044 Single Small Push Button Overtravel Actuator

Operating Characteristics .010" Gap

Operating force	10 oz. max.
Release force	1 oz. min.
Movement diff.	.030 max.
Pretravel	.050 max.
Overtravel	.125 min.

ZTD-0041 Single Panel Mount Toggle Actuator

for detailed specifications and prices write for catalogs "CM" and "Z".

Free engineering service. Our engineers will be happy to pit their professional experience against your tough switching problem. Just tell us what it is . . . we'll recommend ways to solve it. No obligation, of course.

Manufacturers of a complete line of load-tested precision snap-switches and relays.

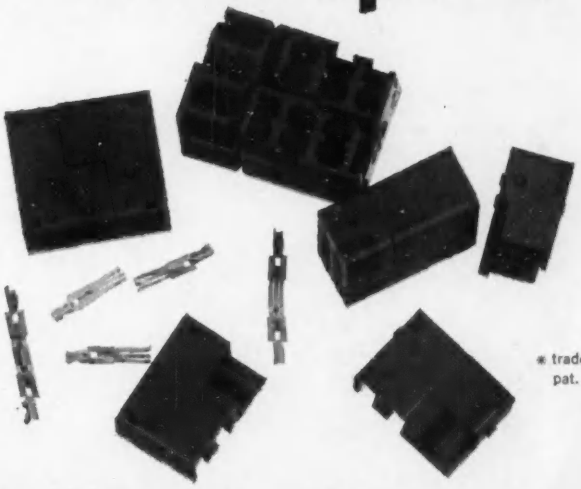
RELAYS ACRO SWITCHES

"OUR 21st YEAR"

ACRO DIVISION Robertshaw

COLUMBUS 16, OHIO

MEET morpho*



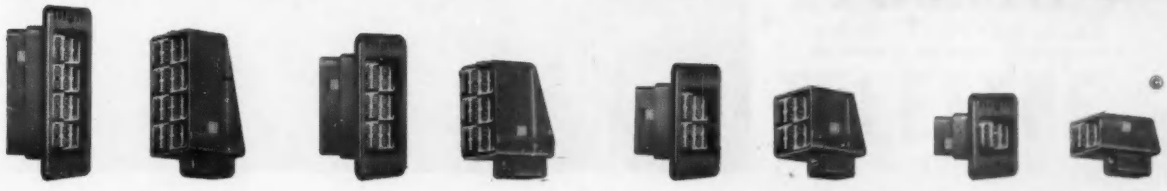
* trademark pat. pend.

THE SYMBOL OF A MOST UNUSUAL NEW DEVELOPMENT BY CANNON

Meet MORPHO—he represents the most versatile plug you ever saw! MORPHO is Cannon Electric Company's unusual *new* development for meeting many industrial and military requirements *inexpensively*. Check these features!• Crimp-type contacts supplied loose for crimping with a simple hand tool, or in belts for crimping with a semi-automatic tool • Easiest installation ever, just snap into insulators, module insulators designed for alternate positioning for maximum adaptability • Hermaphrodite design, contacts and insulators can be used in either plug or receptacle! MORPHO plugs have been tested to severe requirements, are available in different configurations with a wide range of contact layouts. Write for Catalog MH-1 *today* and meet MORPHO for yourself...another reason why you should always consult the *first* name in plugs — why you should *consult Cannon for all your plug requirements.*

CANNON PLUGS

CANNON ELECTRIC CO., 3208 Humboldt St., Los Angeles 31, Calif.



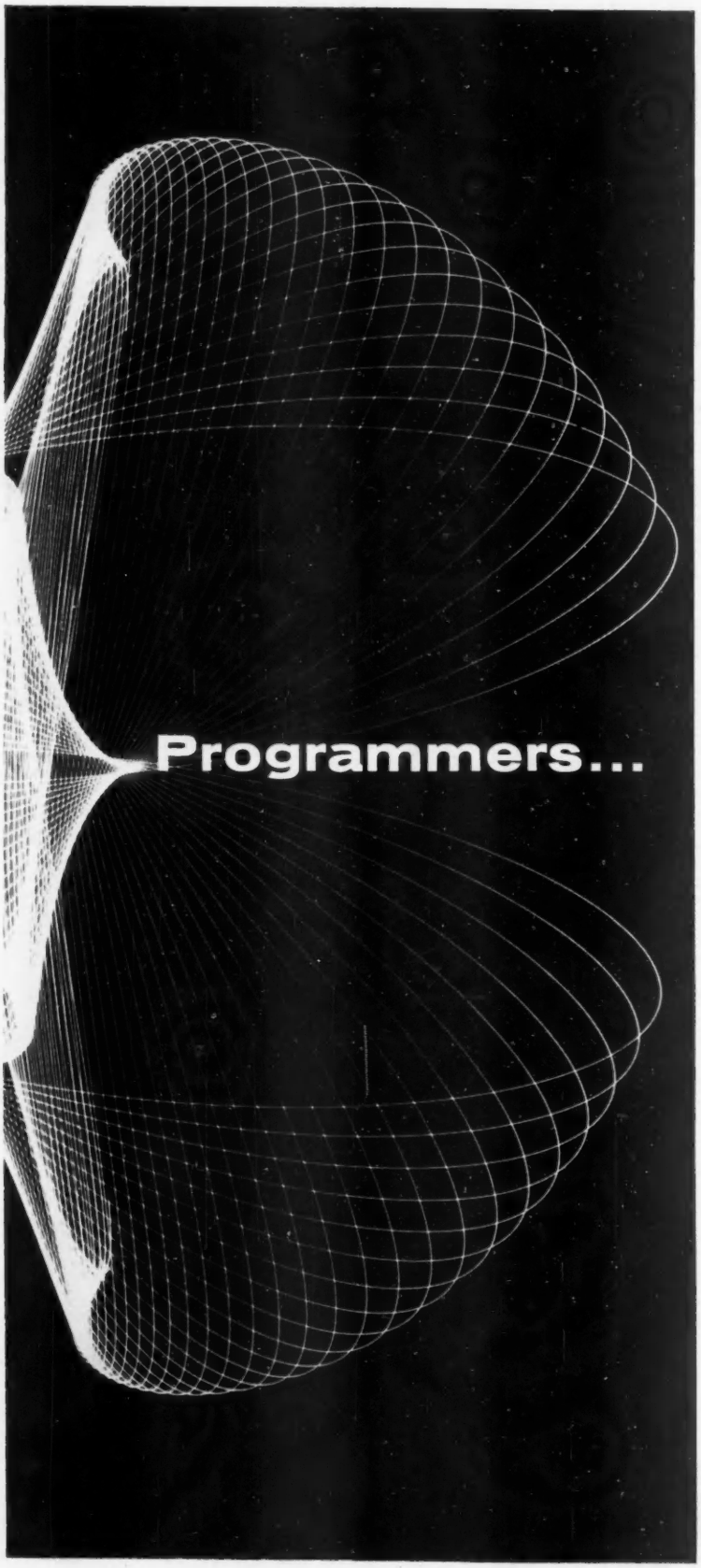
If You Can Call the Shots For New Computers Designed to do New Jobs, You'll Like it at Sylvania's Data Systems Operations

We're looking for Senior Programmers to work out the strategy, control and self-checking features of new computers. Here is your opportunity to make a creative contribution to advancing the state of the art and join the team that developed MOBIDIC, the first mobile digital computer, as well as the data systems for BMEWS and UDOFT.

At Sylvania you'll work on compilers, inventory control systems, translators, real-time system analysis and other projects requiring intensive research and development.

There are both administrative and technical openings at every level with opportunities for advancement at our Needham, Massachusetts research and development center. This new facility is located on Boston's suburban Route 128 in the midst of the nation's largest research complex, and close to the cultural, recreational and educational facilities of Boston.

If you'd like to program your future with Sylvania, write Mr. Ed N. Parry at Sylvania's DSO, Needham, Massachusetts, or telephone collect, HIllcrest 4-3940.



Data Systems Operations/SYLVANIA ELECTRONIC SYSTEMS
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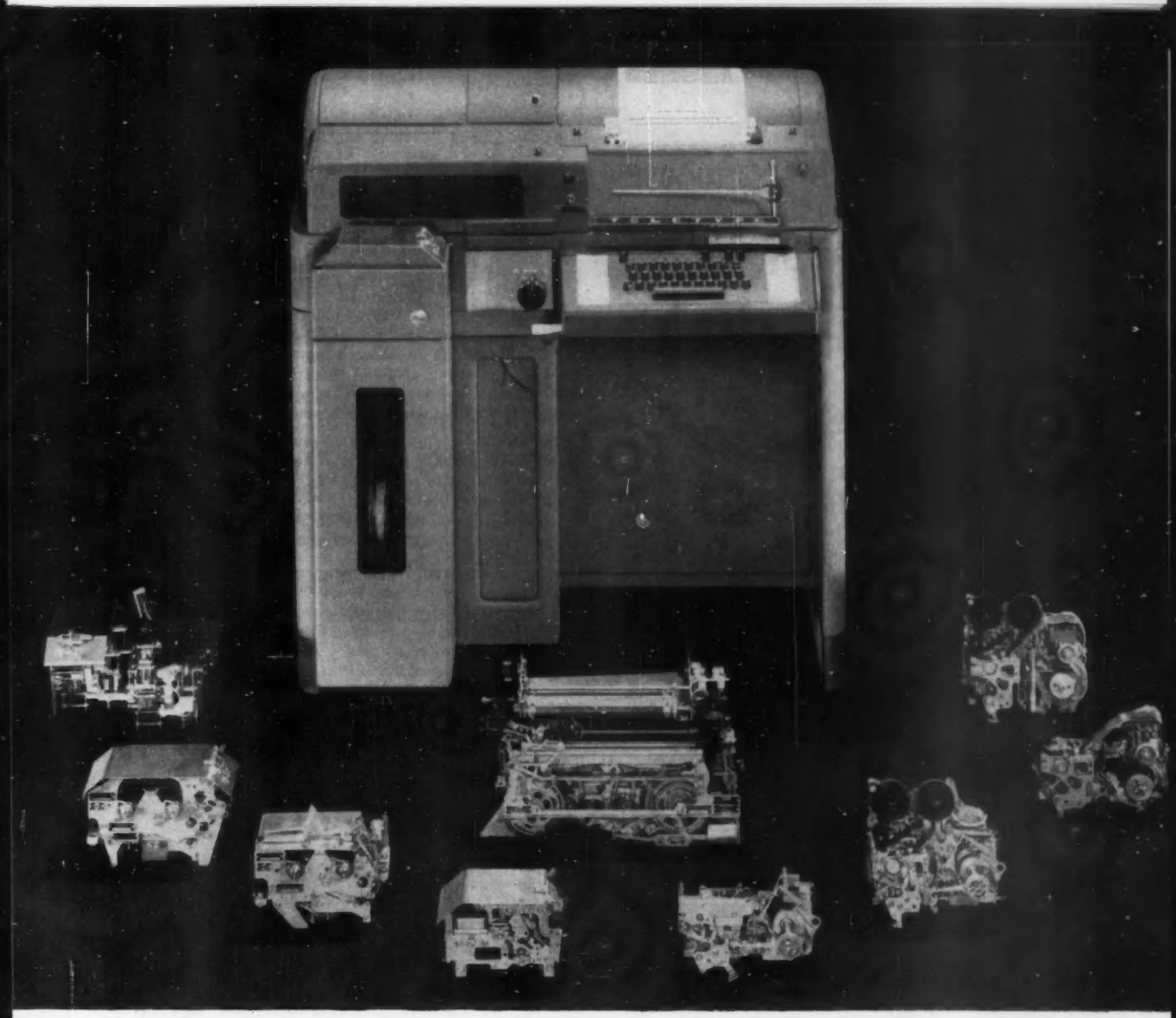


Complete Message Center in one Teletype Machine

A complete message center in a compact cabinet, with a choice of components to best meet your individual needs—that's the story of the Teletype Model 28 automatic send-receive set.

It provides facilities for sending and receiving on message paper or sprocket-fed business forms. In addition, there is a choice of four different tape reader and four different tape punch components—for preparing punched tape and for sending and receiving with tape.

The flexibility of the set is further broadened by a built-in control unit, the "stunt box," which may be equipped for a wide variety of extra features and switching duties—eliminating the need for external apparatus often required for such functions.

The ASR set is a compact, efficient tool to speed communications and cut costly paperwork. Why not investigate what it can do for you?

Typing Tape Punch

Tape Reader

Send-Receive Page Printer

Automatic Send-Receive Set

FREE LITERATURE: Write for Model 28 "Complete Product Line" brochure Teletype Corp., Dept. 26D, 4100 Fullerton Ave., Chicago 39, Illinois.

TELETYPE®
CORPORATION
SUBSIDIARY OF *Western Electric Company* INC.

See Teletype Corporation's equipment exhibit at the Western Joint Computer Conference, May 3-5, San Francisco, California.

CIRCLE 99 ON READER SERVICE CARD

EAI

PACE®

analog computers

meet your needs today —

tomorrow

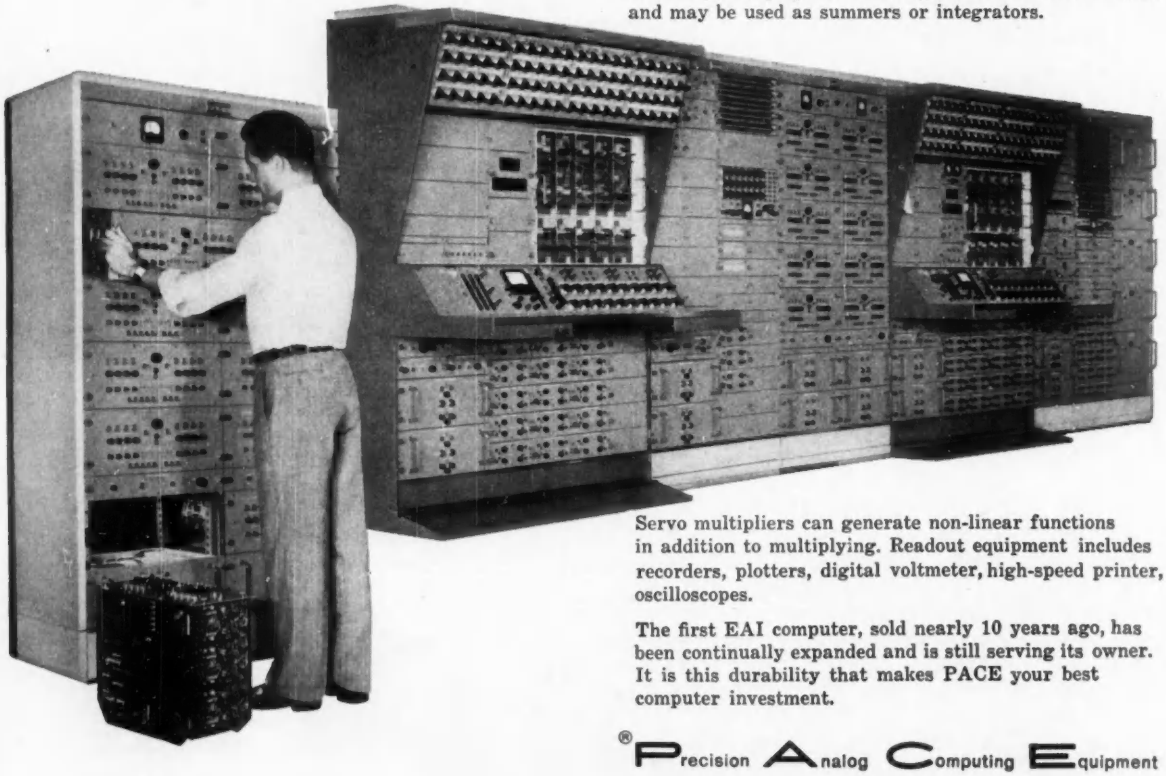
MODULAR DESIGN PROVIDES FLEXIBILITY AND ECONOMY

The PACE 231R is one of the most versatile, flexible computers ever designed. It is composed entirely of standard production line components. As a result, you have the benefit of a custom-built computer without the costs of special design.

You can start with a single console containing 40 operational amplifiers and 20 coefficient potentiometers (or less)—then expand by adding standard plug-in components, stock harnesses, and hardware. No soldering, no cable lacing, no metal work required. A single console can contain up to 80 operational amplifiers, 150 coefficient potentiometers and additional control and operational components.

Large 3450 hole pre-patch panel provides terminations for up to 100 amplifiers, 150 potentiometers, and many assorted linear and non-linear components. When your demands exceed the capacity of the basic console, components can be added in groups—housed in compact, rugged racks which blend perfectly with the basic console.

You can choose from the world's widest line of computing components and accessories. For example, EAI offers 61 different types of servo and electronic multipliers and a wide variety of fixed function generators for performing sin x, cos x, x^2, log x, x^4 and other commonly encountered mathematical operations. For added flexibility, many operational amplifiers are non-committed and may be used as summers or integrators.

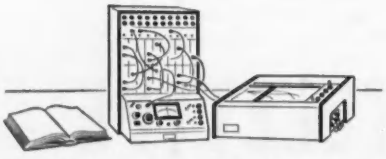


Servo multipliers can generate non-linear functions in addition to multiplying. Readout equipment includes recorders, plotters, digital voltmeter, high-speed printer, oscilloscopes.

The first EAI computer, sold nearly 10 years ago, has been continually expanded and is still serving its owner. It is this durability that makes PACE your best computer investment.

®Precision Analog Computing Equipment

Outstanding opportunities for engineers with proven ability—resumes invited.



New solid-state computer and desktop X-Y plotter.

EAI

ELECTRONIC ASSOCIATES, INC.

Long Branch, New Jersey

See Teletype Corporation's equipment exhibit at the Western Joint Computer Conference, May 3-5, San Francisco, California.

CIRCLE 99 ON READER SERVICE CARD

JAPAN
Joins the Giants

Engineers who visit Japan these days are returning to the U.S. visibly impressed and even shaken. The Japanese, they say, are making faster technological progress than any other country in the world—moving even faster than the much touted Russian technology machine. One control specialist who has toured both Russia and Japan made the point that unlike Russia, Japan has not limited its industrial resurgence to capital goods. Japanese stores are jammed with goods—made in Japan.

New industrial scene

Another technical specialist who has visited Japan a number of times reported after his most recent trip that he hadn't recognized the Japanese industrial scene. "In 1956", he said, "touring a Japanese process plant was like visiting an international fair. You would see instruments from every country in the world—the U.S., Germany, France, every country but Japan. Today, the Japanese plants are spanking new, filled with the latest equipment which is run by the newest in control. Japanese industrialists appear to have a phobia about getting the best and newest control into their plants. And all the new instrumentation is made in Japan, Japanese designed or built in Japan under license."

The big question worrying U.S. business men: will Japan's phenomenal resurgence in industry—and in control in particular—manifest itself in low-priced exports that compete in the U.S. with American-made measurement and control devices? Because present indications are that U.S. makers face bitter competition ahead, CtE took a look at what's behind the Japanese strides.

Squeeze on people

Population is unquestionably the outstanding pressure on Japanese development. If the U.S. had the same population density as Japan, the 1960 U.S. census would run about 3.5 billion instead of a probable 180 million people. And what complicates the problem: only about 20 percent of Japan's limited land area is arable (compared to about 60 percent of the U.S.).

This tremendous population represents a lush market for goods, enough to warrant a tremendous increase in productive capacity. But before these millions of people become consumers, they have to have purchasing power with which to buy goods. Because of the country's cavernous hunger for food and raw materials (most of which must be imported), Japan has to trade manufactured products such as instruments, controls, and consumer products.

Hold the job

The population pressure also affects the quality of technical development in a strange way if you are used to U.S. customs. Engineers are motivated by the most fundamental urge—the desire to survive. For every engineering job there are almost 10 applicants. Loss of a job in Japan is a catastrophic event since a new position cannot be found. The suicide rate among Japanese students is the highest in the world, primarily because there are no jobs to be had.

With such job pressure, engineers are not mobile in Japan. There is practically no movement from one company to another, or one industry to another. Even engineering managers cannot find new jobs.

Industrial emphasis

Japan has been able to accelerate activity in industrial control because there has been no military production or development to sap talent

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and money. Banned from military development by postwar treaties, Japanese control engineers concentrated on process improvement, component development, numerical control of machine tools (CtE, Mar. '60, p. 140), and program control of machinery.

The great destruction of World War II and the period of developmental inactivity which followed left the Japanese far behind Western control technology. But the Japanese turned this lag into an advantage: they have leap frogged intermediate steps. For example, all electronic control has to be transistorized. They've developed their own data logging equipment and instruments like the gas chromatograph based on the latest state of the art.

It has to be good

Quality is being maintained in all goods by strict policing on an industry basis. Most industries forbid their members to export "Chinese copies" of some other country's product (a major change in philosophy; the Japanese were formerly known as ardent copyists). The result is showing up in foreign competition. Recently a Japanese industrialist told an American about a major plant installation he had sold to a foreign country. The Japanese explained matter-of-factly that he had beaten out U.S. competition "because his design was better".

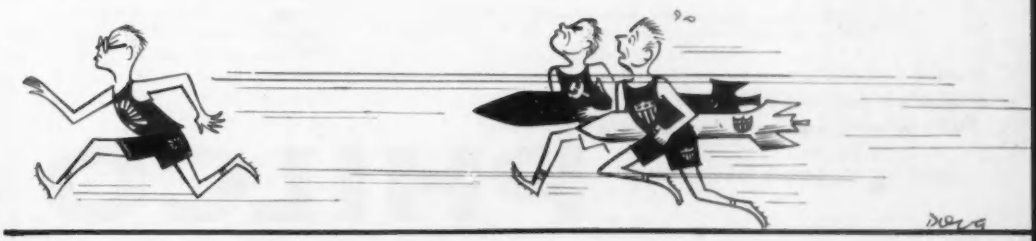
High quality imaginative design may be even a more serious threat to U.S. makers than the lower cost of Japanese equipment. Today, most control experts agree that Japanese theory is on a par with U.S., if not ahead. Japanese professors are currently teaching the latest in control at such colleges as Purdue University, Case Institute, M.I.T., and the University of California. Hardware design has almost caught up; only large scale production lags.

U. S. strong points

How can U.S. makers survive faced with such an array of formidable factors? U.S. control builders still have three factors working for them.

- Application engineering available. For some time, U.S. engineers companies are likely to hold an edge supplying application engineering. For one thing, Japanese engineers are not likely to be so closely acquainted with the practices and engineering habits which are so important in designing a control system.
- Service available. U.S. user companies are likely to be less cordial to foreign service representatives. Overcoming such fears takes a certain amount of inertia and time. And service costs the supplier money. Many Japanese companies would be hard-pressed to supply the kind of service American users demand (and it would have to be paid for at U.S. labor rates).
- Unusual designs in specific areas. Many U.S. instrument and control designs are unique and are likely to remain in that position because of Japan's lack of interest in those areas, lack of capability in them, or because of U.S. ingenuity.

But over the next five years, U.S. manufacturers will do well to concentrate effort on all three of these advantages.



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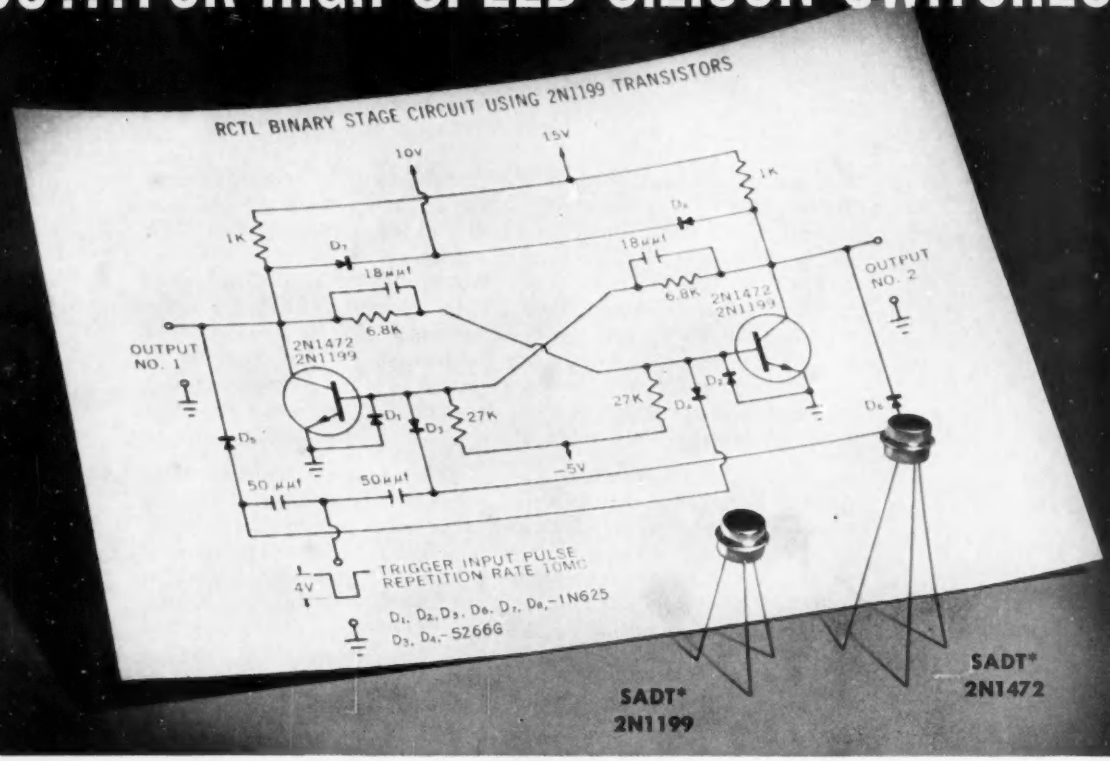

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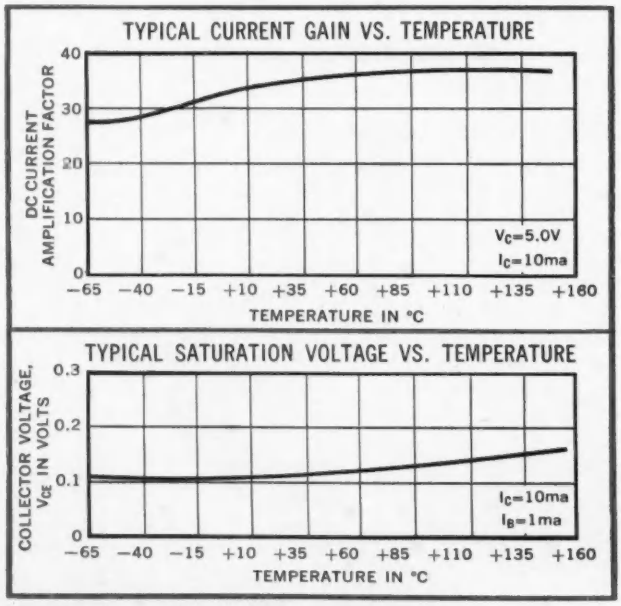

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Reliability Could Become a Disease

Remember the story about the man looking under a street light for his lost wallet? When questioned whether he was certain that he had lost the wallet there, he replied, "No, but this is the only place where I can see to find it." Attempts to demonstrate or measure reliability under forced mathematical restraints are about as fruitful. They may bring to light some desirable improvements in performance, but the engineer can hardly expect them to illuminate true system effectiveness.

Nevertheless, as automatic systems have assumed more critical operating responsibilities in both defense and industry, ways of designing and describing their reliability have become critically important. The scurry to shed light on the matter has generated lots of heat from all sides. Quality control people argue for inspection and evaluation of finished systems. Designers argue for mathematical analysis of reliability while systems are still being engineered. Both are right and both seek numerical means of stating reliability.

Mean Time Between Failure (MTBF) techniques have gained widespread popularity with all parties involved, but they are based on two handy "street light" assumptions: 1) following the debugging period, MTBF is constant with time, and 2) confidence in MTBF measurements depends solely on total test time under uniform conditions. To test these assumptions, raw factory and field MTBF data on supposedly identical fire control systems made by two companies were recently analyzed by Convair Astronautics. To the chagrin of reliability researchers, there was no evidence of constant MTBF. Nor were the specimens uniform enough to verify the second assumption.

A purchaser, whether he's an industrial manufacturer or Uncle Sam, wants to buy automatic systems that are effective. Observing the hullabaloo over MTBF, derating charts, and statistical rules for combining reliability data on components and subsystems, he might conclude that reliability is an engineer's disease. A spokesman for the Air Force Ballistic Missile Division and another for an industrial process contractor have given us, this month, remarkably uniform observations on the fuss. First, they believe that systems designers must continue to seek realistic expressions for reliability. More significant, they said that they'd prefer to do business with companies whose engineers take reliability as so serious an objective that it has become an engineering religion with them. To find such preferred engineers, they look for:

- simplicity of design
- conservative use of components (call it derating)
- continuing search for critical weaknesses

W. E. Vannah

Which of these hp

APPLICATION NOTES

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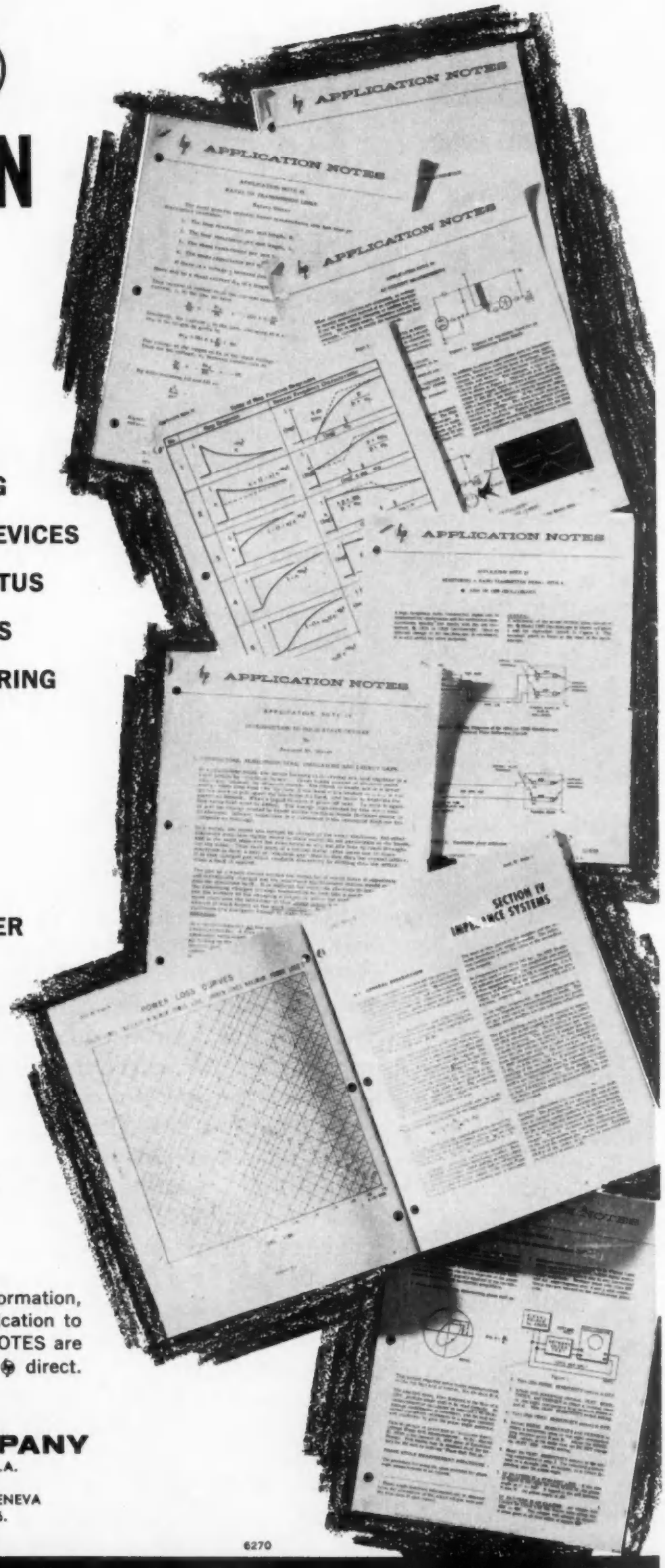

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A Guide to Controlling Continuous-Flow Chemical Reactors

Reactor control first requires the development of transfer functions characterizing the single stirred-tank reactors carrying out a first order, isothermal, irreversible reaction. In particular, control synthesis is then investigated by practical, numerical application of transfer functions relating product concentration to inlet reactant concentration and reactant flow. To facilitate the comparison of alternate control schemes, the author employs the interesting concepts of the relative transfer function and the deviation-ratio curve

OLE ANDREAS SOLHEIM
Chr. Michelsens Institutt, Bergen, Norway

Chemical reactor control keeps constant one or more of these quantities:

- product concentration
- reactants concentration
- conversion
- flow
- reactor temperature

by manipulating one or more of these quantities:

- inlet reactants concentrations
- inlet flow
- inlet stream temperature
- supplied heat

The selection of the appropriate manipulated variable for reactor control depends on such process characteristics as reaction kinetics, reactor dynamics, conversion efficiency, and concentration ratio of split-feed inlet streams.

First-order, isothermal, irreversible reactions follow the rate equation:

$$r = kC_A \tag{1}$$

where r = rate of reaction (k mole per hr-cu meter)
k = reaction velocity coefficient (hr^{-1})
C_A = reactant concentration (k mole per cubic meter)

Types of reactions that follow this equation are:

$$A \rightarrow R; \qquad A \rightarrow R + S$$
$$A + B \rightarrow R; \qquad A + B \rightarrow R + S$$

where concentration of B is so large it remains essentially constant. It is assumed that no change in volume takes place during the reaction.

Reactor Dynamics

The present study of reactor dynamics and control is based on the reaction $A \rightarrow R$, but results can also be applied, with small modifications, to the other reaction types. The reaction $A \rightarrow R$ takes place in a single stirred-tank reactor, Figure 1, the dynamics of which obtain from a material balance:

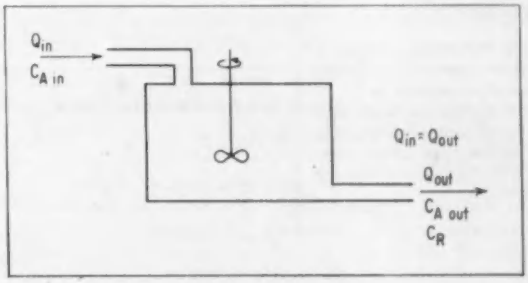
$$V(dC_{A\,out}/dt) = QC_{A\,in} - QC_{A\,out} - kVC_{A\,out} \tag{2}$$
$$V(dC_R/dt) = -QC_R + kVC_{A\,out} \tag{3}$$

Two simplifying symbols are τ, the mean residence time of the fluid in the reactor, and s, the Laplace variable, where $\tau = V/Q$ and $s = j\omega + \sigma$. The assumption is made that complete mixing occurs in the tank, which means no concentration or temperature gradients in the reactor.

Adopting the symbols τ and s, two transfer functions —those relating product concentration and outgoing reactant concentration to inlet reactant concentration—can be derived by writing Equations 2 and 3 as:

$$\tau sC_{A\,out} = C_{A\,in} - C_{A\,out} - k\tau C_{A\,out} \tag{4}$$
$$\tau sC_R = -C_R + k\tau C_{A\,out} \tag{5}$$

FIG. 1. Stirred-tank reactor.



Open-Loop Transfer Functions of Single Stirred-Tank Chemical Reactor

ABSOLUTE TRANSFER FUNCTIONS

- give reactor dynamics on basis of operating values.
- are used for determining system characteristics and synthesizing controller parameters.
- are used for stability studies.

RELATIVE TRANSFER FUNCTIONS

- give directly relative change in output caused by relative change in input.
- eliminate operating-point terms from linearizing nonlinear equations, making functions more general.
- are not usable for stability studies.

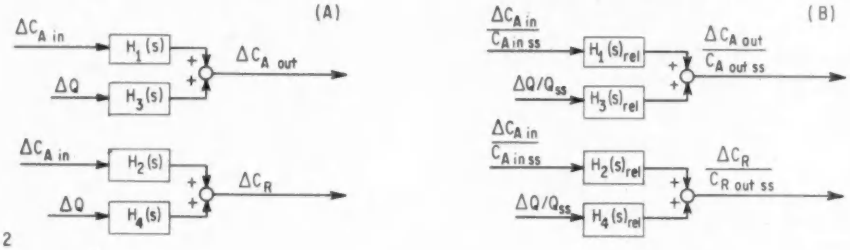


Fig. 2

$H_1 = \frac{\Delta C_{A\,out}}{\Delta C_{A\,in}}$	$(H_1)_{rel} = \frac{(\Delta C_{A\,out})/(C_{A\,out\,ss})}{(\Delta C_{A\,in})/(C_{A\,in\,ss})}$
$H_2 = \frac{\Delta C_R}{\Delta C_{A\,in}}$	$(H_2)_{rel} = \frac{(\Delta C_R)/(C_{R\,ss})}{(\Delta C_{A\,in})/(C_{A\,in\,ss})}$
$H_3 = \frac{\Delta C_{A\,out}}{\Delta Q}$	$(H_3)_{rel} = \frac{(\Delta C_{A\,out})/(C_{A\,out\,ss})}{(\Delta Q)/(Q_{ss})}$
$H_4 = \frac{\Delta C_R}{\Delta Q}$	$(H_4)_{rel} = \frac{(\Delta C_R)/(C_{R\,ss})}{(\Delta Q)/(Q_{ss})}$
$H_1 = \frac{1}{1+k\tau} \times \frac{1}{T_1 s+1}$	$(H_1)_{rel} = \frac{1}{T_1 s+1}$
$H_2 = \frac{k\tau}{1+k\tau} \times \frac{1}{\tau s+1} \times \frac{1}{T_1 s+1}$	$(H_2)_{rel} = \frac{1}{\tau s+1} \times \frac{1}{T_1 s+1}$
$H_3 = \frac{k\tau}{(1+k\tau)^2} \times \frac{C_{A\,in\,ss}}{Q_{ss}} \times \frac{1}{T_1 s+1}$	$(H_3)_{rel} = \frac{k\tau}{1+k\tau} \times \frac{1}{T_1 s+1}$
$H_4 = -\left[\frac{k\tau}{(1+k\tau)^2} \times \frac{C_{A\,in\,ss}}{Q_{ss}} \times \frac{1}{T_1 s+1}\right]$	$(H_4)_{rel} = -\left[\frac{1}{1+k\tau} \times \frac{1}{T_1 s+1}\right]$
$H_1 = (1-\eta) \times \frac{1}{\eta(s/k)+1}$	$(H_1)_{rel} = \frac{1}{\eta(s/k)+1}$
$H_2 = \eta \times \frac{1}{\eta(s/k)+1} \times \frac{1}{\left(\frac{\eta}{1-\eta} \times \frac{s}{k}\right)+1}$	$(H_2)_{rel} = \frac{1}{\left(\frac{\eta}{1-\eta} \times \frac{s}{k}\right)+1} \times \frac{1}{\eta(s/k)+1}$
$H_3 = \eta(1-\eta) \times \frac{C_{A\,in\,ss}}{Q_{ss}} \times \frac{1}{\eta(s/k)+1}$	$(H_3)_{rel} = \frac{\eta}{\eta(s/k)+1}$
$H_4 = -\left[\eta(1-\eta) \times \frac{C_{A\,in\,ss}}{Q_{ss}} \times \frac{1}{\eta(s/k)+1}\right]$	$(H_4)_{rel} = -\left[(1-\eta) \times \frac{1}{\eta(s/k)+1}\right]$

USE NORMALIZED FREQUENCY $\omega\tau$

- for plotting Bode diagrams for reactor stability studies.
- for comparing dynamics of several reactors with different flows (Q) and volumes (V), where $\tau = V/Q$.

USE NORMALIZED FREQUENCY ω/k

- for comparing dynamics of a given reactor for different values of conversion η.
- for comparing static sensitivity of controlled variable to changes in different manipulated variables—set $s = 0$ at right.

$T_1 = \frac{\tau}{1+k\tau}$ $\quad \eta = \frac{k\tau}{1+k\tau}$ $\quad \tau = V/Q$ When performing frequency response set: $s = j\omega$

Rearranged, Equation 4 and 5 yield transfer functions:

$$H_1(s) = \frac{\Delta C_{A\,out}}{\Delta C_{A\,in}}(s) = \frac{1}{\tau s + 1 + k\tau}$$

$$= \frac{1}{1 + k\tau} \times \frac{1}{T_1 s + 1} \quad (6)$$

$$H_2(s) = \frac{\Delta C_R}{\Delta C_{A\,in}}(s) = \frac{k\tau}{1 + \tau s} \times \frac{1}{\tau s + 1 + k\tau}$$

$$= \frac{k\tau}{1 + k\tau} \times \frac{1}{\tau s + 1} \times \frac{1}{T_1 s + 1} \quad (7)$$

where $T_1 = \tau/(1 + k\tau)$ (8)

The second set of transfer functions—those relating product concentration and outgoing reactant concentration to flow—is also derived from Equations 2 and 3. These differential equations must first be linearized (Ref. 1) since they are nonlinear with respect to Q. The resulting transfer functions are:

$$H_3(s) = \frac{\Delta C_{A\,out}}{\Delta Q} = \frac{C_{A\,in\,ss}}{Q_{ss}} \times \frac{k\tau}{(1 + k\tau)^2} \times \frac{1}{T_1 s + 1} \quad (9)$$

$$H_4(s) = \frac{\Delta C_R}{\Delta Q} = -H_3(s) \quad (10)$$

where ss means steady-state value obtained by setting $s = 0$. The dynamics of a single stirred-tank reactor can now be represented by Figure 2A, preceding page.

Reaction efficiency

It is appropriate to review the significance of the terms $k\tau$ appearing in the preceding transfer functions. Conversion η is a measure of reaction efficiency and is defined as:

$$\eta = [(C_{A\,in} - C_{A\,out})/(C_{A\,in})]_{ss} \quad (11)$$

From Equation 6:

$$C_{A\,out\,ss} = (C_{A\,in\,ss})/(k\tau + 1) \quad (12)$$

Substituting for $C_{A\,out\,ss}$ in Equation 11 yields:

$$\eta = (k\tau)/(1 + k\tau) \quad (13)$$

or

$$k = \eta/(1 - \eta) \quad (14)$$

Thus $k\tau$ is also a measure of reaction efficiency.

The relative transfer function

Additional insight can be gained in reactor dynamics and control by introducing the *relative* transfer function, which offers certain benefits over the usual *absolute* transfer function. By example, the relative transfer function is defined as:

$$H_4(s)_{rel} = \frac{\Delta C_R/C_{R\,ss}}{\Delta Q/Q_{ss}} = \frac{Q_{ss}}{C_{R\,ss}} H_4(s) \quad (15)$$

Thus only the static terms are different; the dynamic terms remain the same. The relative transfer function gives directly the relative change in output caused by a given relative change in input, a fact frequently of greater interest than absolute values. For instance, "A 10 percent change in flow Q causes a 5 percent change in product concentration" is often more meaningful than the equivalent expression "A 0.1 cu meter per hr change in Q causes a 0.5 k mole per cu meter change in product concentration." However, the relative transfer function cannot be used in stability studies.

To obtain $H_4(s)_{rel}$, the steady-state value of reactant concentration $C_{A\,in\,ss}$ is determined from Equation 7 by setting $s = 0$, so that:

$$C_{A\,in\,ss} = (C_{R\,ss})(1 + k\tau)/(k\tau) \quad (16)$$

Then, applying Equation 16 to Equation 15, the relative transfer function is:

$$[H_4(s)]_{rel} = -\frac{1}{1 + k\tau} \times \frac{1}{T_1 s + 1} \quad (17)$$

The three other relative transfer functions can be developed in a similar manner. The dynamics of the reactor may now be represented—in terms of the relative transfer functions—by the block diagram shown in Figure 2B, facing page.

The four absolute and four relative transfer functions for the tank reactor are listed in the top two rows of the table—ready for plotting the transfer functions as Bode diagrams for control studies in terms of the normalized frequency $\omega\tau$. However, it is often desirable to compare static and dynamic characteristics of a given reactor for various values of conversion η. For such cases the Bode diagrams are plotted in terms of normalized frequency ω/k. Thus for example, $H_1(s)$ becomes:

$$H_1(\omega/k) = (1 - \eta)[(\eta\omega/k) + 1] \quad (18)$$

The table also lists the eight transfer functions in terms of the normalized frequency ω/k.

STEP I: SELECTING THE REACTOR'S MANIPULATED VARIABLE

A quick evaluation based on steady-state system conditions.

The transfer functions listed in the table offer an opportunity to select the best type of reactor control system for existing processing conditions. In what follows, the control system is assigned the task of maintaining product concentration C_R constant in the face of disturbances arising from changes in inlet reactant concentration $C_{A\,in}$ and flow Q. That is, control can be obtained by manipulating $C_{A\,in}$ or Q. Even for a limited situation like this there are several alternate control configurations. Some of these are discussed, first on a steady-state basis to determine which variable to manipulate, and second on a dynamics basis to synthesize the controller parameters which best reduce the effect of disturbances.

Manipulate total flow for low-conversion reactions

Total flow is an easy variable to manipulate, Figure 3. Unfortunately there is a practical restriction. Reactor control by flow manipulation is effective only at relatively small values of conversion η. This can be readily demonstrated by examining the steady-state values of $H_3(\omega/k)_{rel}$ and $H_4(\omega/k)_{rel}$ in the transfer function table on the preceding page.

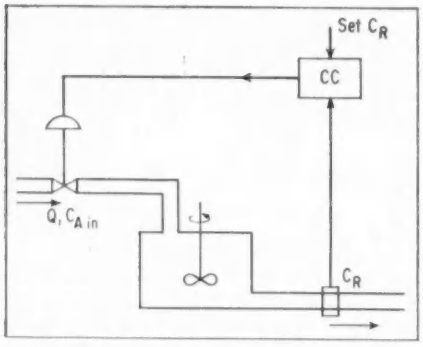


FIG. 3. For low-conversion reactions, use flow manipulation. CC is concentration controller.

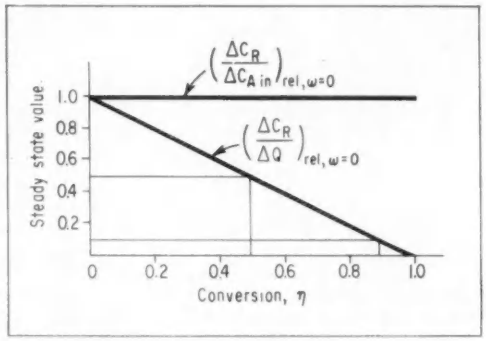


FIG. 4. Static values of transfer functions vs conversion show sensitivity of product concentration to changes in inlet reactant concentration and flow.

The steady-state values of these transfer functions vs η are plotted in Figure 4. Here, with $\eta = 0.9$, a 10 percent change in $C_{A\,in}$ causes a 10 percent change in C_R. To counteract this disturbance a change of $10/0.1 = 100$ percent change in flow has to be applied, and this flow range is very impractical. However at a low conversion, say $\eta = 0.5$, the necessary change in flow to counteract a 10 percent change in $C_{A\,in}$ is $10/0.5 = 20$ percent, a value which is within practical limits. The conclusion is that a chemical reactor control system with flow manipulation, Figure 3, is useful only when reactions are carried out with low conversion.

Manipulate split-feed concentration for high-conversion reactions

Mixing two streams of different concentrations, Figure 5, is another way to carry out chemical reactions. Reactor controllability depends on the concentration ratio of the two streams. Two cases will be examined:

In the first case, $Q_1 >> Q_2$ and $C_{A1\,in} << C_{A2\,in}$, so that the change in flow due to inlet concentration manipulation is negligible. Using the graphs of Figure 4 again, it can be seen that this arrangement offers no difficulties in counteracting disturbances in $C_{A\,in}$ or in Q when conversion is high. However as will be shown later, some restrictions are placed on controller settings to secure sufficient process stability.

Manipulate split-feed flow for low- and high-conversion reactions

In the second case the concentration ratio of the two inlet streams, Figure 5, is not too great, so that the changes in total flow and reactant inlet concentration have to be taken into account. By preference on a steady-state basis, manipulation is carried out on the stream with the strong concentration, here Q_2. When two flows with a concentration ratio of at least two or three are available, the manipulation of Q_2 to control product concentration is a useful arrangement for both low and high conversions.

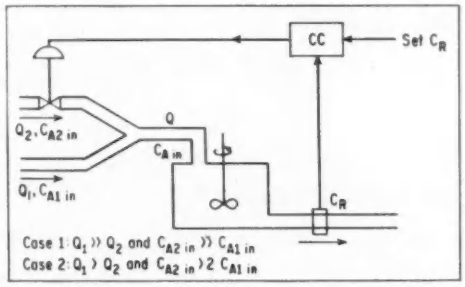


FIG. 5. When using split-feed, the valve in one stream manipulates either inlet reactant concentration or flow.

STEP II: DESIGNING CHEMICAL REACTOR CONTROLLERS

A thorough analysis based on reactor dynamics

To illustrate the procedure for designing chemical reactor control systems, three numerical examples will be worked out in considerable detail. In doing so, the dynamics of all elements in the loop other than the controller and the process itself are assumed negligible. The insert, next page, contains the pertinent process information for the numerical examples.

Manipulating total flow

Returning now to the arrangement of controlling product concentration by manipulating total flow, Figure 3, the corresponding block diagram for analyzing closed loop control can be drawn, Figure 6. Here, a change in inlet reactant concentration acts as a disturbance. Because $H_4(s)$, containing only one time constant, is in the control loop, the overall gain can be set as high as desired without causing system instability. With high gain from a proportional controller, the offset caused by disturbances will usually be satisfactorily small. Ordinarily then, a proportional plus reset controller will not be needed.

Flow manipulation has been shown, on a static basis, to work well for a 0.5 conversion. Using 0.5 conversion and the values from the insert, the closed-

loop transfer function is:

$$M(s) = \frac{K_p H_4(s)}{1 + K_p H_4(s)} = \frac{K_p}{1 + K_p} \times \frac{1}{\frac{0.5}{1 + K_p}\tau s + 1} \quad (19)$$

With proportional control gain $K_p = 20$ (or more correctly minus 20 since $H_4(s)$ is negative) then:

$$M(s) = \frac{20}{21} \times \frac{1}{\frac{1}{42}\tau s + 1} \quad (20)$$

From Figure 6:

$$\frac{\Delta C_R}{\Delta Q} = \frac{H_4(s)}{1 + K_p H_4(s)} = \frac{1}{K_p} \times M(s)$$

$$= -\frac{1}{21} \times \frac{1}{\frac{1}{42}\tau s + 1} \quad (21)$$

Then $$\left(\frac{\Delta C_R}{\Delta Q}\right)_{rel} = \frac{\Delta C_R}{\Delta Q} \times \frac{Q_{ss}}{C_{R\,ss}} = \frac{\Delta C_R}{\Delta Q} \times \frac{2}{4}$$

$$= -\frac{1}{42} \times \frac{1}{\frac{1}{42}\tau s + 1} \quad (22)$$

$$\frac{\Delta C_R}{\Delta C_{A\,in}} = \frac{H_2(s)}{1 + K_p H_2(s)}$$

$$= \frac{1}{42} \times \frac{1}{\tau s + 1} \times \frac{1}{\frac{1}{42}\tau s + 1} \quad (23)$$

and $$\left(\frac{\Delta C_R}{\Delta C_{A\,in}}\right)_{rel} = \frac{\Delta C_R}{\Delta C_{A\,in}} \times \frac{C_{A\,in\,ss}}{C_{R\,ss}}$$

$$= \frac{1}{21} \times \frac{1}{\tau s + 1} \times \frac{1}{\frac{1}{42}\tau s + 1} \quad (24)$$

Closing the loop and using a controller gain of 20 reduces considerably the effect of disturbances on product concentration. In the steady state, obtained by setting s in Equations 22 and 24 to zero, a 10 percent change in flow causes a $(1/42) \times 10 = 0.24$ percent change in product concentration, and a 10 percent change in inlet reactant concentration causes an 0.48 percent change in product concentration.

Figure 7 contains the dynamics information for the reactor controlled by flow manipulation. Note that in addition to the closed-loop system transfer function and the two closed-loop relative transfer functions, the figure also contains the plots of the two relative transfer functions (from the table) plotted on an open-loop basis. Thus, Figure 7 shows the extent to which closed-loop control attenuates disturbances. Another way of looking at control quality is by deviation-ratio curves, a technique described in the box, next page.

Manipulating split-feed concentration

Figure 9 is the block diagram of the closed-loop control system manipulating inlet reactant concentration for the first case of split feed, when $Q_1 >> Q_2$ and $C_{A2\,in} >> C_{A1\,in}$. The process transfer function $H_3(s)$ inside the closed control loop contains two time constants, see table. With a proportional controller the gain K_p cannot exceed a certain value (to be determined) to secure sufficient stability. The stability criterion is a resonant peak value $M_p = 1.3$, Figure 10.

Although previous analysis indicated the inlet reactant concentration manipulation is effective at high

Process values used in numerical examples

For stirred tank reactor,

$C_{A\,in\,ss} = 8\ k$ moles per cu meter

$Q_{ss} = 2$ cu meters per hr

When $\eta = 0.5$, $k_T = 1$

Then $C_{R\,ss} = \eta C_{A\,in\,ss} = 0.5 \times 8 = 4$ moles per cubic meter

When $\eta = 0.9$, $k_T = 9$

Then $C_{R\,ss} = 0.9 \times 8 = 7.2$ moles per cu meter

Therefore, when $\eta = 0.5$:

$$H_2(s) = 0.5 \times \frac{1}{\tau s + 1} \times \frac{1}{0.5\,\tau s + 1}$$

$$H_4(s) = -\frac{1}{0.5\,\tau s + 1}$$

When $\eta = 0.9$

$$H_2(s) = 0.9 \times \frac{1}{\tau s + 1} \times \frac{1}{0.1\,\tau s + 1}$$

$$H_4(s) = -0.09 \times 4 \times \frac{1}{0.1\,\tau s + 1}$$

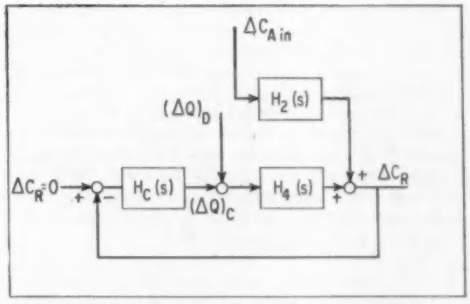


FIG. 6. Block diagram of reactor when manipulating total flow. The closed-loop compensates for disturbances in inlet reactant concentration as well as changes in flow.

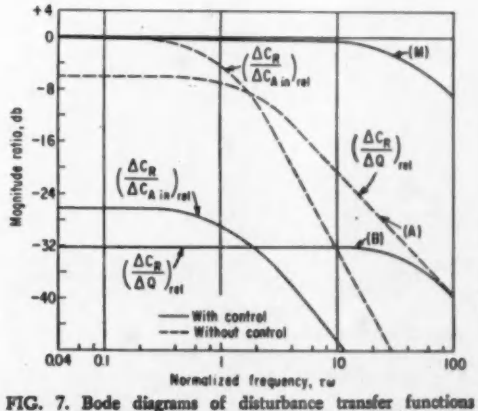


FIG. 7. Bode diagrams of disturbance transfer functions when using flow manipulation at a conversion of 0.5, a value previously determined on a steady state basis.

Use Deviation Ratio Curves to Compare Control Quality of Alternate Control Arrangements

Deviation ratio curves (Ref. 2) are a measure of quality of control. A d-r curve is the ratio of disturbance attenuation with and without control. Such a curve can be obtained by calculating a single transfer function of the ratio and plotting it vs $\omega\tau$. However the d-r curve is more easily obtained by drawing the two relative transfer functions (with and without control) in the same magnitude vs frequency diagram and subtracting (when using the db scale) the "without control" function from the "with control" function.

This procedure is carried out, by way of example, for $H_4(s)_{rel}$ developed for the reactor controlled by flow manipulation. The result is curve A, Figure 8, as obtained from curves A and B in Figure 7. Note that the deviation ratio is the same for all disturbances regardless of where they enter the system.

Figure 8 also contains d-r curves for four other control arrangements discussed in the article, and the set of curves can be used to compare the control quality of the several control configurations.

Deviation ratio curves have a characteristic shape. Great attenuation occurs in the low frequency region, which means that for disturbances with frequencies in this region, the system performs much better with control than without. In the high frequency region the process itself has a high attenuation, the ratio approaches unity (zero db), and control thus has little effect. In the medium frequency region it is possible that the ratio is greater than unity, which means the system is better without control. For the case of flow manipulation, the ratio is always less than unity because the closed control loop has only one time constant, and no resonance peak occurs.

Deviation ratio curves demonstrate the importance of knowing the frequency spectrum of disturbances when estimating control system merits.

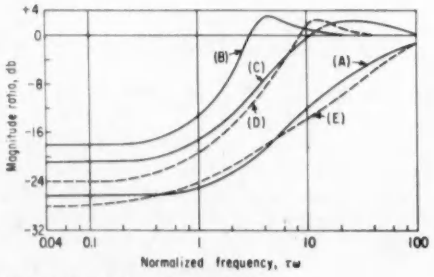


FIG. 8. Deviation ratio curves of numerical example for reactor control systems described in the text.

conversion, the present example will be worked out for $\eta = 0.5$ to permit a comparison of results with flow manipulation. For $\eta = 0.5$, the open-control loop transfer function with proportional control only is:

$$K_p \times H_2(s) = K_p \times 0.5 \times \frac{1}{\tau s + 1} \times \frac{1}{0.5\tau s + 1} \quad (25)$$

Using the Nichols chart (Ref. 3), the value of K_p at $M_p = 1.3$, is 14. The resulting closed-loop system transfer function $M(s)$ is plotted in Figure 11.

From the block diagram, Figure 9, the following transfer functions can be determined:

$$\frac{\Delta C_R}{\Delta C_{A\,in}}(s) = \frac{H_2(s)}{1 + K_p H_2(s)}$$

$$= \frac{1}{K_p} \times M(s) = \frac{1}{14} \times M(s) \quad (26)$$

$$\left(\frac{\Delta C_R}{\Delta C_{A\,in}}\right)_{rel} = \frac{\Delta C_R}{\Delta C_{A\,in}} \times \frac{C_{A\,in\,ss}}{C_{R\,ss}}$$

$$= \frac{1}{14} \times \frac{8}{4} \times M(s) = \frac{1}{7} \times M(s) \quad (27)$$

In a similar manner the following transfer functions are derived:

$$\left(\frac{\Delta C_R}{\Delta Q}\right)(s) = -\frac{\tau s + 1}{7} \times M(s) \quad (28)$$

$$\left(\frac{\Delta C_R}{\Delta Q}\right)_{rel} = -\frac{\tau s + 1}{14} \times M(s) \quad (29)$$

The closed-loop relative transfer functions, Equations 27 and 29, are plotted in Figure 11 along with their open-loop (without control) counterparts. The corresponding deviation ratio curve is plotted in Figure 8, curve B. Since this is a system with two time constants, a closed-loop resonance occurs so there exists a frequency region for curve B in which system performance is better without control than with.

System performance can be improved by extending the frequency region in which the deviation ratio is less than unity. This is accomplished by adding rate, or derivative, action (*PD* control) to the controller. Then the controller transfer function is assumed to be:

$$H_c = K_p \times \frac{0.5\tau s + 1}{0.05\tau s + 1} \quad (30)$$

Figure 12 is the proportional-plus-rate controller's frequency response plot. The zero at $\tau s = -2$ in the controller cancels the pole at $\tau s = -2$ in the process (see Equation 25), so the controller merely adds a new pole at $\tau s = -20$ which is of less importance than the remaining pole at $\tau s = -1$ in the process.

With rate action added, the transfer function of the open control loop is now:

$$K_p \times 0.5 \times \frac{1}{\tau s + 1} \times \frac{1}{0.05\tau s + 1} \quad (31)$$

Even though the value of K_p that makes $M_p = 1.3$ is about 60, the maximum gain available from industrial controllers due to proportional mode is only about 20. Using this value of 20 in Equation 31, the relative transfer functions can be developed in a manner similar to that used in finding Equations 27 and 29. The new relative transfer functions with rate action added are also plotted in Figure 11, with the corresponding deviation ratio plotted as curve C in Figure 8.

Some improvement has been obtained by using rate

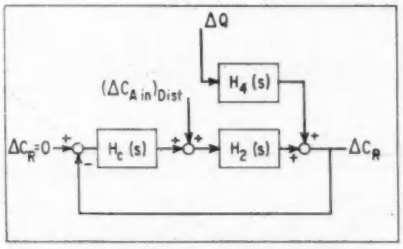


FIG. 9. Block diagram of split-fed reactor when concentration ratio of two streams is large so that change in flow is negligible.

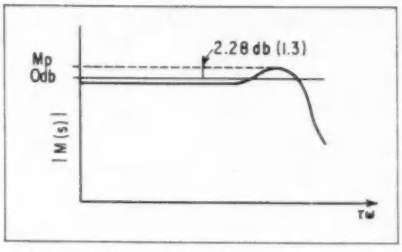
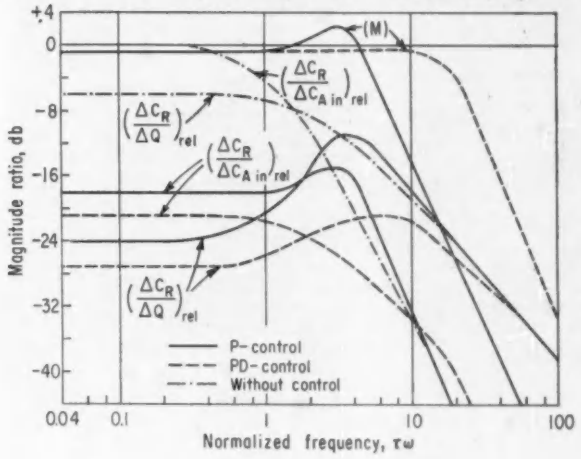


FIG. 10. Stability criterion is based on peak resonance of 1.3, or 2.28 db.

FIG. 11. Bode diagrams for system of Figure 9 with proportional control and proportional-plus-rate control. Corresponding deviation ratio curves are B and C, Figure 8.



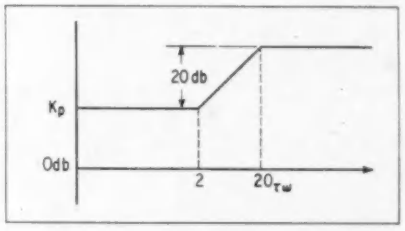


FIG. 12. Frequency response of proportional-plus-rate controller.

action in conjunction with inlet reactant concentration manipulation, but comparing deviation ratio curves A, B, and C in Figure 8, it is seen that flow control is a better system than inlet reactant concentration control with either proportional or proportional-plus-rate actions when conversion is 0.5. Curve D (not developed here) is for inlet reactant concentration manipulation when conversion is 0.9, a more practical choice as shown previously. Curve E is the deviation ratio for the final numerical example: manipulating split-feed flow.

Manipulating split-feed flow

If $C_{A2\ in}$ in Figure 5 is not much greater than $C_{A1\ in}$, the change in total flow Q has to be taken into account when one of the split-feed streams, Q_1 or Q_2, is manipulated:

$$Q_1C_{A1\ in} + Q_2C_{A2\ in} = (Q_1 + Q_2)C_{A\ in} = QC_{A\ in} \quad (32)$$

$$C_{A\ in} = \frac{Q_1C_{A1\ in} + Q_2C_{A2\ in}}{Q_1 + Q_2} \quad (33)$$

Rewriting Equation 33 to show the effect of small changes and rearranging the equation results in:

$$\Delta C_{A\ in} = \frac{Q_{1ss}}{Q_{ss}}\Delta C_{A1\ in} + \frac{Q_{2ss}}{Q_{ss}}\Delta C_{A2\ in} + \frac{C_{A1\ in\ ss} - C_{A\ in\ ss}}{Q_{ss}}\Delta Q_1 + \frac{C_{A2\ in\ ss} - C_{A\ in\ ss}}{Q_{ss}}\Delta Q_2 \quad (34)$$

Equation 34 aids in preparing the block diagram, Figure 13, of the chemical reactor whose product concentration is maintained constant by adjusting a split-feed stream flow. This block diagram is more complicated than previous ones because the two feed streams each have two disturbances to be taken into account. The manipulated variables must now counteract the combined effect of three unmanipulated disturbances. The block diagram arbitrarily shows Q_2 as the manipulated variable in the closed loop, but further study is needed to determine whether manipulating Q_1 or Q_2 is better.

To obtain numerical transfer functions for comparison with previous control arrangements, the following process values are assigned:

$C_{A1\ in}$ = 6 k moles per cu meter
$C_{A2\ in}$ = 14 k moles per cu meter
Q_1 = 1.5 cu meters per hr
Q_2 = 0.5 cu meters per hr
Q = 2.0 cu meters per hr

Therefore from Equation 33:

$$C_{A\ in} = \frac{6 \times 1.5 + 14 \times 0.5}{1.5 + 0.5} = 8\ k \text{ moles per cu meter}$$

with $\eta = 0.9$, then $C_R = 0.9 \times C_{A\ in} = 7.2\ k$ moles per cu meter.

One absolute transfer function will be derived next, from Figure 13, in literal form as an example:

$$\frac{\Delta C_R}{\Delta Q_1}(s) = \left[\frac{C_{A1\ in\ ss} - C_{A\ in\ ss}}{Q_{ss}}\right]H_2(s) + H_4(s) \quad (35)$$

Then, the open-loop relative transfer functions in numerical form are:

$$\frac{\Delta C_R}{\Delta Q_1}(s) = -1.26 \times \frac{0.29\tau s + 1}{(\tau s + 1)(0.1\tau s + 1)} \quad (36)$$

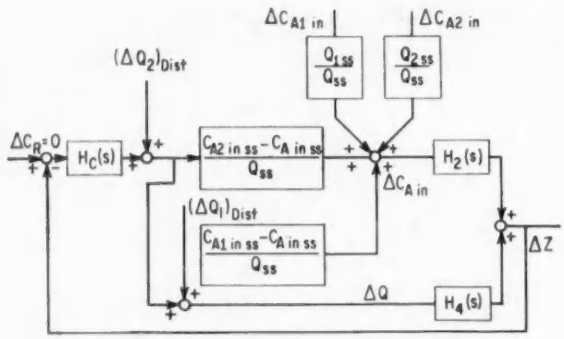


FIG. 13. Block diagram of split-fed reactor when $C_{A2\ in}$ is not much greater than $C_{A1\ in}$. Here manipulating flow of one stream affects both total flow and inlet reactant concentration.

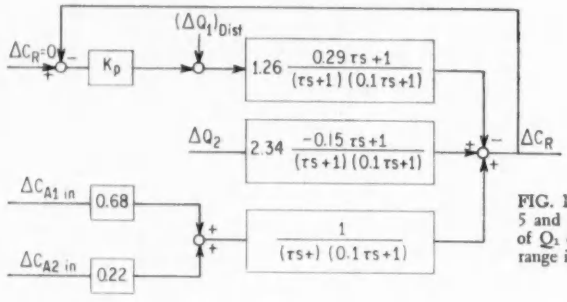


FIG. 14. Bode diagrams of system of Figures 5 and 13 with conversion equal to 0.9.

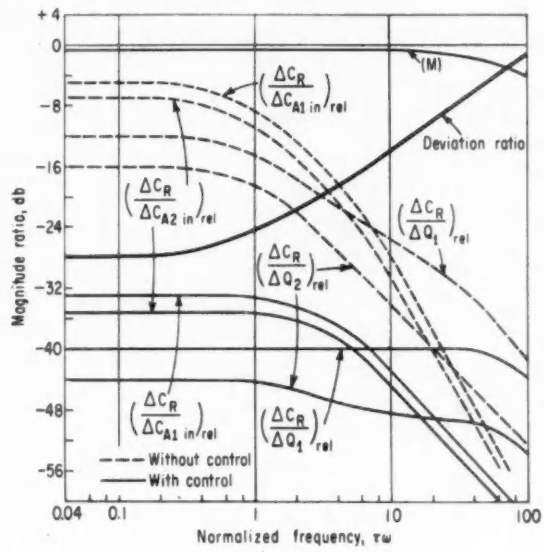


FIG. 15. On dynamics basis the system of Figures 5 and 13 is better controlled by manipulation of Q_1 even though the total flow varies over a greater range in the steady state to counteract disturbances.

$$\left(\frac{\Delta C_R}{\Delta Q_1}\right)_{rel} = -0.26 \times \frac{0.29\tau s+1}{(\tau s+1)(0.1\tau s+1)} \quad (37)$$

$$\frac{\Delta C_R}{\Delta Q_2} = 2.34 \times \frac{-0.15\tau s+1}{(\tau s+1)(0.1\tau s+1)} \quad (38)$$

$$\left(\frac{\Delta C_R}{\Delta Q_2}\right)_{rel} = 0.16 \times \frac{-0.15\tau s+1}{(\tau s+1)(0.1\tau s+1)} \quad (39)$$

$$\frac{\Delta C_R}{\Delta C_{A1\ in}}(s) = 0.68 \times \frac{1}{(\tau s+1)(0.1\tau s+1)} \quad (40)$$

$$\left(\frac{\Delta C_R}{\Delta C_{A1\ in}}\right)_{rel} = 0.56 \times \frac{1}{(\tau s+1)(0.1\tau s+1)} \quad (41)$$

$$\frac{\Delta C_R}{\Delta C_{A2\ in}}(s) = 0.22\ \frac{1}{(\tau s+1)(0.1\tau s+1)} \quad (42)$$

$$\left(\frac{\Delta C_R}{\Delta C_{A2\ in}}\right)_{rel} = 0.44\ \frac{1}{(\tau s+1)(0.1\tau s+1)} \quad (43)$$

The relative functions are plotted in Figure 14 as the "without control" graphs.

Of interest are the coefficients in Equations 37, 39, 41, and 43. They are the steady-state values of the open-loop transfer functions and as such are useful in determining the sensitivity of the controlled variable to the manipulated variable. A 10 percent change in $C_{A1\ in}$ causes a $10 \times 0.56 = 5.6$ percent change in C_R. To cancel the disturbance requires either a $5.6/0.26 = 21.5$ percent change in Q_1 (corresponding to a 16 percent change in total flow Q), or $5.6/0.16 = 35$ percent change in Q_2 (or 8.7 percent change in Q). On a steady state basis, then, if the smaller the change in total flow the better, Q_2 is to be manipulated.

However the dynamics must also be considered. Note that transfer function $(\Delta C_R/\Delta Q_2)$, Equation 38, has one zero in the right half of the complex s-plane and two poles, thus making the phase angle approach minus 270 deg at large ω. But $(\Delta C_R/\Delta Q_1)$, Equation 36, has the zero in the left half-plane, and consequently the phase angle approaches 90 deg.

With $(\Delta C_R/\Delta Q_2)$ inside the control loop there is a good possibility of instability, so the permitted gain must be small, about $K_p = 2$ for $M_p = 1.3$. However with $(\Delta C_R/\Delta Q_1)$ inside the control loop, there are no restrictions on K_p, so from dynamics considerations Q_1 is the logical stream to manipulate. Assuming the moderate static flow rangeability of Q_1 is acceptable, then it becomes even more reasonable in the present case to manipulate Q_1.

The block diagram for Q_1 manipulation to control product concentration is shown in Figure 15. With $K_p = 20$, the transfer function of the open loop is:

$$20 \times 1.26 \times \frac{0.29\ \tau s+1}{(\tau s+1)(0.1\tau s+1)} \quad (44)$$

The equivalent closed-loop transfer function, $M(s)$, is shown in Figure 14 along with the corresponding disturbance transfer functions "with control". Finally, this same figure shows the deviation-ratio curve for the system. This d-r curve is also plotted as curve E in Figure 8, affording a comparison of quality of control of the various chemical reactor control systems described here.

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Evaluating Today's Proximity Switches

Proximity switches have proven immunity to the fatal malady that has long plagued limit switches—being "beaten to death" by the very thing they are supposed to detect. Despite this desirable feature, however, proximity devices are not yet "ideal" switches. So proximity switches vs limit switches is still a lively topic of debate for control engineers.

TABLE I
Characteristics of the "Ideal" Presence-Sensing Switch

- Reliability ✓
- Adequate number of contacts ✓
- Fail-safety ✓
- Low operating force ✓
- Sufficient power handling capacity ✓
- Simplicity ✓
- Snap action ✓
- Ability to sense without contact ✓
- Small size ✓
- Easy to mount and wire ✓
- Low cost ✓
- Provision for ample overtravel ✓
- Accuracy ✓
- Fast operation ✓
- Small differential ✓
- Reliability ✓
- Positive action ✓
- Insensitive to environment ✓
- "Fool-proofness" ✓

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In the field of machinery control, there is a frequent requirement for electrical switching elements having the facility of "presence sensing". Such switches open or close an external circuit when they are contacted or approached by some moving part of the machine or by the product passing through the machine. Stopping a tool slide automatically at the end of its ways or actuating a capping mechanism when a can is correctly positioned under it are examples of control functions that are usually initiated by some type of presence sensing switch. The well known limit switch has monopolized the full range of applications calling for presence sensing. Very recently, noncontacting or proximity switches have come into being as a result of attempts to find presence sensors that lack some of the shortcomings of conventional limit switches and come closer perhaps to the characteristics of the "ideal" switch.

The ideal presence-sensing switching device should be completely reliable, simple, positive, fail-safe, foolproof, accurate, fast operating, small in size, low in cost, easy to mount and wire, and suitable for use in all environments. In addition, it should have an adequate number of contacts, sufficient power handling capacity, snap action, small differential, low operating force, ability to sense without contact, and provision for ample overtravel.

The characteristics of the ideal presence-sensing switching device are summarized in the checklist of Table I. There are certain applications that need additional features like multiple contacts, but such requirements are out of the ordinary and are not considered essential for a standard switch.

Unfortunately no ideal presence-sensing device is yet available. Although both limit switches and proximity switches meet many of the specifications, neither is a universally applicable device. Even limit switches, which are standardized to some degree, must be made available in a profusion of different types to best meet the widely varying needs of control applications. And at the present time there is no standardization at all of proximity switches in regard to either sensing elements or control units. In fact although all are somewhat similar in general principle, no two use the same type or size sensing element, and the control engineer must shape his design to suit the particular unit used.

Rating the limit switch

To pave the way for a more objective view of proximity switches, it is advisable to check first how the limit switch rates as a presence sensor. Prac-

TABLE II
COMPARATIVE STANDINGS OF PRESENCE-SENSING SWITCHES

	Mechanical Limit Switches	Vane-operated Limit Switch	Proximity Switches
Reliability	2	1	1
Simplicity	1	1	3
Positive action	1	2	3
Fail-safety	1	2	3
"Fool-proofness"	1	2	3
Accuracy	1	2	3
Operating speed	3	2	1
Size (sensing unit only)	2	3	1
Size (overall)	1	2	3
Cost	1	2	3
Mounting & wiring	1	1	2
Suitability for adverse environment	3	2	1
Number of contacts	1	3	2
Power-handling capacity	1	3	2
Snap action	1	2	2
Differential	1	2	3
Operating force	2	1	1
Sensing without contact	—	2	1
Provision for overtravel	2	1	1

tically all limit switches contain a set of contacts which are operated by a lever or plunger through a "load-and-fire" mechanism. The latter provides the snap action that is important for long contact life and improved accuracy. Most limit switches include a normally open and normally closed contact, although some precision types have but one terminal between one side of the normally open and normally closed contacts. The common terminal is a detriment for many applications, particularly when the extra contacts of the limit switch are to be used for safety interlocking.

Limit switches are simple, positive, accurate, easy to mount and wire, and low in cost. For most applications they have an adequate number of contacts, sufficient power handling capacity, good snap action, and small differential. When applied properly mechanically and without excessive current load through the contacts, limit switches are highly reliable. Their main limitation is in certain applications where they are exposed to chips and coolant which can cause failure of the limit switch. They cannot be used where it is necessary to sense parts without physical contact, nor in applications such as counting where extremely fast response is required, nor where operating life spanning hundreds of millions of operations is called for. Limit switches can be used satisfactorily as input devices in static control systems, but care must be taken to insure that the contacts are suitable for low power level operation.

A comparison of limit switches and other presence-sensing switching devices is summarized in Table II. This chart should be considered as tentative, particularly because much operating data remains to be gathered. It will, however, serve as a guide for determining what type is best for different applications and for quickly reviewing the relative merits of the three types of switching devices.

Proximity switches

Fairly complete information from four different manufacturers of proximity switches was available for detailed study. This information consisted of both technical data and advertising brochures. In addition, some information was obtained from manufacturing plants where proximity switches have been installed. A fifth type of noncontacting switch examined in the course of this analysis was the General Electric Co. vane switch which is really a hybrid—resembling in some respects both proximity switches and limit switches. In this report, therefore, a distinction will be made between vane switches and proximity switches, and they will be discussed separately.

All four of the proximity switches considered are appreciably different from the standpoints of both size and the type of components and circuits employed. In three models, sensing elements and control units are separate. A fourth manufacturer includes everything except the output relay in a single unit but is in the process of developing a new design with the sensing element separate.

No two manufacturers have sensing elements of the same size or type of mounting. Three work completely on a 60-cycle supply, while the fourth operates the sensing element at a much higher frequency. The higher frequency makes this unit more sensitive to nonferrous as well as ferrous materials. Two of the units studied rely on tube amplifiers, while the other two use static elements. Three of the four are normally supplied with relay output, and the fourth can operate a relay as an output load. All can feed signals to static control elements.

The outstanding feature of proximity switches is their ability to sense the presence of a part or operating element without actual physical contact. In general the part to be sensed must be of a ferrous material, although one proximity switch can also sense nonferrous objects. The operating range normally runs from a few thousandths up to an inch, but proximity switches can be obtained with ranges up to several feet. One proximity switch manufacturer offers very small sensing elements for installation where space is restricted. One unit, 2¼ in. long

and mounting in a $\frac{5}{8}$ in.-18 threaded hole, functions even while submerged in cutting oils or coolants.

When properly applied, proximity switches are quite reliable. They can be made extremely fast in operation and in combination with static switching elements form a control system that is suitable for operation in adverse environments. Proximity switches, on the other hand, are not as simple and positive, nor as fail-safe as limit switches. They normally have a larger differential and do not exhibit a "snap action" equivalent to that of a limit switch. The cost of proximity switches runs from six to ten times that of limit switches. Some types require shielded leads between the sensing element and the control unit. This makes wiring somewhat more difficult, particularly when the length of lead between the sensing element and the control unit is important. Precautions must be taken at junction points in the shielded cable, such as at terminal boards.

Vane-operated limit switch

This device, Figure 1, is relatively new and is neither a true limit switch nor a proximity switch. It is designed to give leverless operation without as much cost or as many mounting problems as proximity switches. It does not require a separate power supply and provides long operating life.

The switch is energized by the passage of a soft steel vane through a recessed slot in the switch. The vane, attached to the mechanism to be controlled, disturbs a balanced magnetic field causing two small contacts to close or open when the vane passes through the slot. The contacts, which are sealed, are located between two permanent magnets. Normal stray magnetic fields, metallic objects such as tools, or presence of magnetic dust and chips in the slot will not cause false operation.

When properly applied, the vane-operated limit switch will give reliable operation. It is simple and easy to understand and, like a limit switch, is relatively easy to mount and wire. Most of its characteristics fall in between the limit switch and proximity switch, as shown in Table II.

The major limitation of the vane-operated limit switch is that it can be provided with a single contact only. This must be specified when purchased as normally open or normally closed. The contact used is designed for long life when operating a low coil current relay but is somewhat inadequate in power handling capacity.

Some specific data relative to noncontacting switches of various manufacturers follows.

Westinghouse Electric Corp. The Westinghouse proximity switch, Figure 2, delivers an electrical output of 0.335 amp at 24 vdc, which is adequate to drive both static control elements and 24-vdc relays and solenoids. The switch consists of two parts. The first is an encapsulated sensing element measuring roughly 2 x 2 x $1\frac{1}{4}$ in. which contains an open C-core and two windings connected in a variable reluctance bridge circuit. The second part is a steel-encased, encapsulated control element that includes a balance circuit, amplifier, phase detector, precision flip-flop circuit, transistor output amplifier, and power supply. Dimensions of this element are about 6 x 3 x $7\frac{1}{2}$ in.

Installed, the sensing element is positioned so that the ferrous machine part to be detected passes across the face of the element within a trip distance that is adjustable between $\frac{1}{8}$ to $\frac{1}{2}$ in., or with a second sensing element, between $\frac{1}{8}$ to 2 in. When magnetic material enters the critical zone selected, it causes the sensing bridge circuit to be unbalanced. The signal resulting is then passed to the control element where it is converted into the 24-volt output for driving subsequent control devices. Power supply required is standard 117 vac. When the machine part is $\frac{1}{8}$ in. away from the sensing element, snap-action switching occurs after 0.015-in. travel of the machine part. Response is rapid—the output from the control element lags the signal from the sensing element by only 0.025 sec. The unit is capable of up to 20 operations per sec and is impervious to shock, vibration, corrosion, and humidity.

Price of a complete proximity switch is about $105.

Micro Switch. The new Honeywell proximity switch consists of a sensor and a separate amplifier with a plug-in relay, Figure 3. The amplifier uses transistor circuitry in contrast to the two-stage magamp built into the original versions of the switch. The sensing element contains a four-arm inductance bridge which is normally balanced for zero output. However, when ferromagnetic material is brought near the coils, the balance is upset and a signal is fed to the remotely located bistable amplifier. The amplifier operates the DPDT relay, which can be wired to the output circuits in the same manner as a conventional limit switch. The two components of this new unit may be located up to 150 ft apart without the use of shielded wire. The sensor measures $1\frac{5}{8}$ x $1\frac{5}{8}$ x $3\frac{3}{4}$ in., has a stainless steel face, and is potted in a metal enclosure. The amplifier measures $4\frac{1}{2}$ x 7 x $4\frac{1}{4}$ in. The new unit has an adjustable sensitivity range of $\frac{1}{8}$ to $\frac{1}{2}$ in. and is energized from 115-volt, 60-cycle power.

The relay rating is a 5 amp at 125 vac with a quoted electrical life of 10 million operations. Mercury-wetted contact plug-in relays which have a longer life expectancy are also available. Response of the proximity switch is affected by object size, distance to sensor, and sensitivity setting. The range for operate is 35 to 50 millisec (time for relay contacts to operate after part is placed in front of sensor) and 50 to 85 millisec for release. Under favorable combinations of size, spacing, and sensitivity, operating rates as high as 700 per min can be achieved.

Stability characteristics vary with rate of travel of part, line voltage regulation, amplifier temperature, and sensor temperature. Some typical data were recorded with a 2 x 2 x 1-in. part moving perpendic-

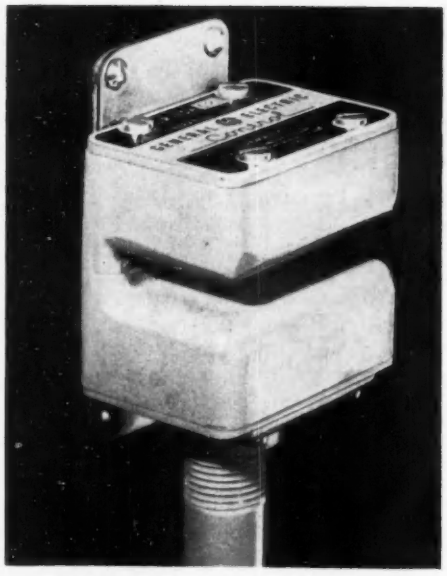

FIG. 1. Vane switch requires passage of flat piece of metal through slot to initiate contact transfer.

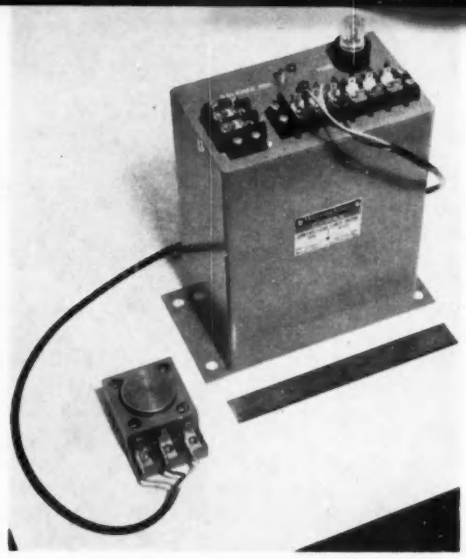

FIG. 2.
Westinghouse version of proximity switch is designed for compatibility with static switching systems.

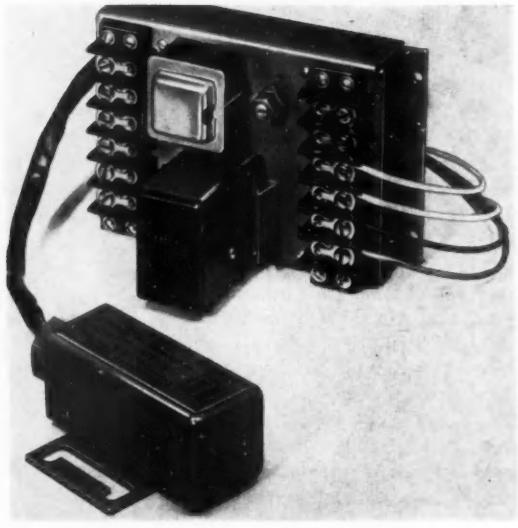

FIG. 3.
New Honeywell proximity switch features transistorized amplifier replacing original magamp.

ularly to the sensor face at a rate of 1 in. per min, ambient temperature between 80 and 90 F, sensitivity setting of $\frac{3}{8}$ in. The operating point was found to shift within plus or minus $\frac{1}{16}$ in. after system temperature had stabilized and line voltage had fluctuated through a 105- to 127-volt range. It will vary within only plus or minus 0.005 in. when voltage regulation is held to 1 percent or less. The operating point is reduced (approaches the sensor face) by $\frac{1}{32}$ in. as the result of heating of the sensor coils.

The OEM price of the sensor-amplifier package in large quantity orders is about $85.

Square D Co. The Square D proximity switch is a 60-cycle device operating on the differential transformer principle. The transducer has a single core with three coils, two of which are energized from a 3-volt supply to set up a standing magnetic field. The third or pick-up coil feeds back into the amplifier panel a voltage signal whose phase depends on the net flux of the ac magnetic fields. When the field is disturbed by entry of a ferromagnetic material, the resulting change in the phase of the signal voltage is detected and amplified in the first stage of the control panel. The second or output stage of the panel may be a pair of thyratrons or a relay, as required by the application.

The standard transducer (V2) is 6 in. long, 2 in. in diameter. All surfaces except the face are magnetically shielded so that the sensitive area of the transducer can be focused on a specific area. The transducer has a nominal sensitivity of 1 in. for a large part, Figure 4. For smaller parts sensitivity is progressively less. Transducers can be obtained with integral sensitivity adjusting screws, encapsulated in plastic for underwater mounting, and for either normally open (off) or normally closed (on) operation. The transducer ambient temperature range is 0 to 45 C. The trip point is materially affected by higher temperatures.

Although there is a slight magnetic pull caused

by the field surrounding the transducer, it is not great enough to hold chips or filings as long as the unit is not mounted face up. The transducer is provided with a 8-ft shielded cable as standard equipment, although cable runs up to 100 ft are feasible. Temperature and voltage affect accuracy of the transducer. Where maximum repeat accuracy is needed, the switch power supply is left on continuously for temperature stabilization. After a 3-hr warmup and with 10 percent variations in line voltage, the switch will be actuated by a part located 1 in. plus or minus $\frac{1}{16}$ in. away from the transducer. If line voltage is held exactly at 115 volts, the accuracy can reach plus or minus $\frac{1}{64}$ in.

The relay panel is suited for most applications involving 900 or fewer operations per minute. The thyratron output panel has a built in hold circuit that allows sufficient time for the output tubes to fire even when the monitored part is within the sensing range of the transducer for only a fraction of a second. It is thus recommended for applications where the required speed of operation exceeds 900 operations per min. Adapters in either AND or OR configuration are available to permit operation of a single panel from two or more transducers. Both AND and OR adapters can be furnished with two or four inputs.

List price for a transducer and a relay panel is about $145.

Electro Products Laboratories. This system is unique in that it responds to ferrous and nonferrous metals of any thickness. Aluminum foil is an example of a hard-to-detect material handled successfully by this proximity switch. The control panel includes a modified Hartley oscillator whose tank coil is contained within the remote pickup. Metal coming into the field of the coil presents an additional loading to the oscillator which in turn stops oscillating. Then the output tube conducts to energize the load relay on the panel. A distinguishing feature of the line is the availability of a wide variety of sizes and shapes of pickups to detect different forms and types of objects. Depending on the pickup, selected sensitivities range from a small fraction of an inch up to a foot. In this design the pickup does not attract metal chips and thus may be mounted in any desired position.

In a second version of the Electro Products proximity switch, the presence of metal at the sensing probe is used to start oscillation. This system approaches a fail-safe type of circuit in that all components of the switch must be in perfect operating condition before a signal is obtained. There is only one circuit condition that can result in a false signal, and this is the removal of the bias from the final tube. Bias voltage is obtained from a separate winding on the power transformer through a solid-state rectifier drawing essentially no current. Therefore the chance of failure of this bias supply is remote. The circuit is more critical in regard to cable length than standard proximity switches and is designed for use with a 10-ft shielded cable.

The vacuum-tube circuitry employed in the control panel is easily modified to provide "delayed make–fast break" or "quick make–slow break" type of output action with the passage of parts in front of the pickup. Zero speed indication can also be obtained. Although relay output is standard, the control panel can be made to supply 5-vdc pulse output. Operating speeds as high as 3,600 per min are practical.

List price for a basic pickup-panel combination is about $115.

General Electric Co. The latest version of the vane operated limit switch is about one-third smaller and will cost about one-third less than the previous model. It is available in either front or top operated models, normally open or normally closed, single-pole contacts, with or without an indicating light. A mounting plate with either form can be rotated 90 deg to permit flexible mounting arrangements. All components are encapsulated within metal enclosures. Operating life of the new model is claimed to be over 250,000,000 operations when used with static controls requiring only 10-ma input. Operation of the device is consistent within plus or minus 0.0025 in. providing that the path of the vane is maintained. Response time of the switch is approximately 0.001 sec.

The normal contact rating is 115 vac, 0.2 amp make or break. A maxiuum rating of 115 vac, 0.75 amp is obtainable. In single-pole, single-throw design, the switch meets JIC requirements. It can operate at any angle and has a cast aluminum enclosure described as oil, dust, and water resistant. Size of the top-operated form without indicating light is $2\frac{11}{16}$ x $2\frac{3}{4}$ x $2\frac{3}{8}$ in. exclusive of mounting plate. The operating vane can be any magnetic iron or steel up to $\frac{5}{16}$ in. thick and $1\frac{1}{2}$ inches wide. The

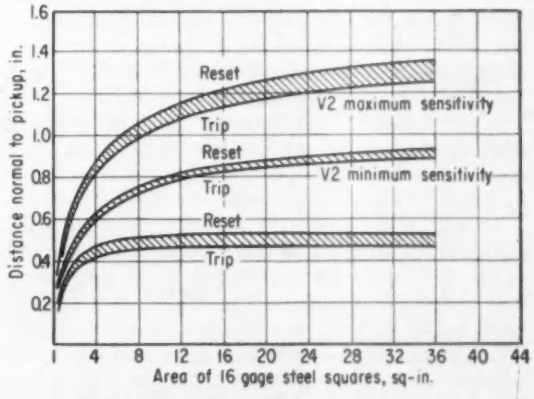

FIG. 4. Trip-reset characteristics of two versions of Square D pickups (V2 and V6) show differential bands characteristic of proximity switches.

TABLE III
CRITICAL SWITCH COMPONENTS

Switch Type	Component
Mechanical limit switch	Contacts Springs Seals
Vane-operated limit switch	Contacts Seal
Proximity switch (with electronic tubes and output relay)	Sensing element Tubes Relay coil Relay contacts
Proximity switch (with static elements and output relay)	Sensing element Relay coil Relay contacts

TABLE IV
EFFECTS OF TYPE OF LOAD ON SWITCH LIFE

Device	Life in Millions of Operations When Controlling 00 Relay	Small Relay	Static Control
Mechanical limit switch	5+	30+	50+
Vane-operated limit switch	5+	30+	250+
Proximity switch	—	30+	500+

slot through which the vane passes is $\frac{3}{8}$ in. wide. Cost of the switch is about $40.

Application Factors

The importance of a sensing device "failing safe" varies, depending upon the application. If the proximity switch is being used for a counting or permissive control function, failure of the device to work is normally less detrimental than if the device is being used to stop the motion of a machine slide. The most careful consideration must be given in selecting devices for applications where wrecks can occur or safety of the operator is imperiled by faulty operation of the sensing device.

To obtain the maximum degree of safety, circuits are generally arranged so that all relays and solenoid valves will open when stopping is to take place. The chances of a relay sticking closed or a solenoid valve failing to open are considered much less likely than the failure of a relay coil, relay contact, or the solenoid coil. Thus, the safety burden is put upon the simplest type of mechanical operation. In a typical application of this sort, a slide is stopped by opening the normally closed contact of a limit switch, which may operate the corresponding solenoid valve directly or through relays. Assuming the limit switch is properly applied and protected, and with the contacts operated positively by the lever arm, this method is considered to be the most reliable for obtaining trouble-free operation.

Proximity switches, on the other hand, often depend upon the actuation of a relay to give the same contact opening provided directly by the limit switch in the above example. Now if tubes are used in the amplification stage prior to the relay and these tubes fail, erroneous operation may result with consequent failure to stop at the required point. Because tubes can fail either conducting or nonconducting, it is normally not considered good practice to use any device containing electronic tubes in critical applications, except of course where there is no alternative. Proximity switches using static elements feeding into static control may be more suitable for fail-safe circuitry. However these devices also fail in either direction so that careful consideration must be given before they are applied in critical situations.

A comparison of the relative costs of limit, vane-operated limit, and proximity switches indicates that the last cost between six and 10 times as much as do limit switches, with the vane-operated limit switch in between. It has been said, and rightly so, that trouble-free operation warrants the use of reliable and more expensive components. Although in some respects proximity switches are more reliable than limit switches, proper application of limit switches can narrow the reliability gap tremendously. The great cost differential between the two types certainly justifies careful design and installation.

With regard to operating life, it is difficult to give specific estimates because there are so many factors that affect it. Table III lists the most critical components of the various sensing devices. For this chart it is assumed that the proximity switches employ relay output. The contacts are the major life-limiting weakness in all devices. And the nature of the external load has a direct bearing on contact wear, as shown in Table IV. Where life is a problem, the most logical answer would appear to be to always use a static-type proximity switch feeding into static-type elements. In some applications this is true, but it is not feasible in others because of cost and other limitations. It is interesting that reports from users indicate that proximity switches are not proving as reliable as they theoretically should be.

For the foreseeable future there will be an increasing field for proximity switches and vane-operated limit switches, and use of limit switches will continue at a high level. Because all three, properly used, will give satisfactory and reliable operation, the control engineer need not restrict himself to one type only. Well designed systems will undoubtedly use both limit switches and proximity switches in a manner where they work together for better and more reliable control of machines.

Techniques of Dynamic Display

Part II: Optics at Work

Author Barker describes how the laws of optics help put up-to-date information into the hands of human operators when the information continually changes at a high rate. This is the second article in a three-part series on techniques of dynamic display. The first article, which appeared in February 1960, covered cathode ray tubes; article number two describes:

- **projection techniques and hardware**
- **mirror and filter techniques and hardware**
- **third dimension techniques and hardware**

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Optical principles have been harnessed in dynamic display equipment to accomplish one or more of the following functions:

- To increase the size of an image
- To introduce color
- To separate an image from ambient light
- To create a third dimensional effect

For study, various approaches can be classified into three groups: 1) projection techniques in which a small image is magnified, 2) mirror and filter techniques in which light sources and images are combined to form a composite image at an observer's eye, and 3) third dimension techniques.

Projection Techniques

Most usual reason for projecting a display is to enlarge it. To do this, the brightness of the smaller image has to be greater than the brightness of the larger. The ratio of the brightness of the smaller image to that of the larger will be equal to the ratio of the area of the large image to the area of the small one. Input brightness can be supplied by the same device that presents the smaller image, or it can be provided by an auxiliary light source.

A configuration frequently used in projecting systems is called Schmidt optics; it allows the production of an image that is free of astigmatism and haziness at the edges. Shown in simplified form in Figure 1, the Schmidt system focuses the image with a spherical mirror. Spherical aberration is reduced by an aspherical correction plate located at the center of curvature of the reflector. Schmidt optics are more efficient than refractive optical systems, but the

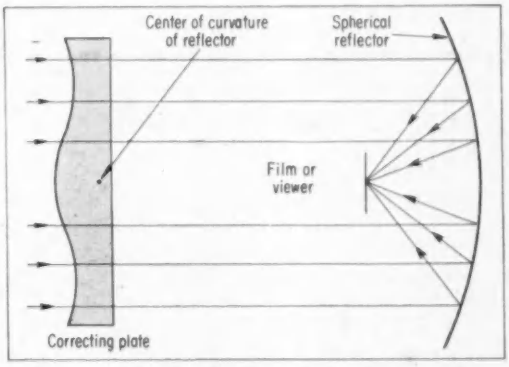


FIG. 1. Schmidt optical system is the basis of many projection techniques.

INDEX TO DISPLAY TECHNIQUES (PART II)

Projection Techniques	
TV projection	General Precision Laboratory*
	Trad Electronics Corp.
EMI Projection Technique	EMI Research Laboratories Ltd.
DVST Projectors	Farnsworth Div. of IT&T
	Radio Corp. of America
Spot Projector	Fenske, Fedrick, & Miller
Sky Screen	Northrop Corp.
Eidophor System	General Electric Co.
Fast Film processors	Kenyon Instrument Co.
	Kelvin and Hughes Co.
Dry Film processor	IMP Engineering Co.
Time Compression	Navy Electronics Laboratory
Mirror and Filter Techniques	
Trinoscope	Telechrome, Inc.
Radar superimposition	Westinghouse Electric Corp.
Ultrasonic light modulation	Fairchild Controls Corp.
Third Dimension Techniques	
Cursor Coordinated Display	Bell Telephone Laboratories
Iconorama	Fenske, Fedrick, & Miller

* Div. of General Precision, Inc.

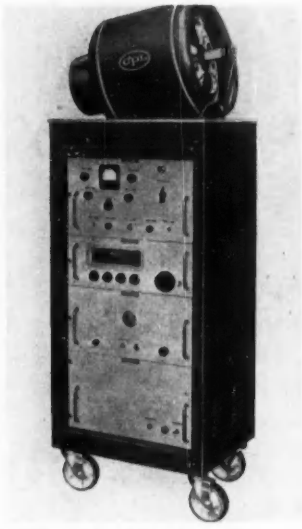
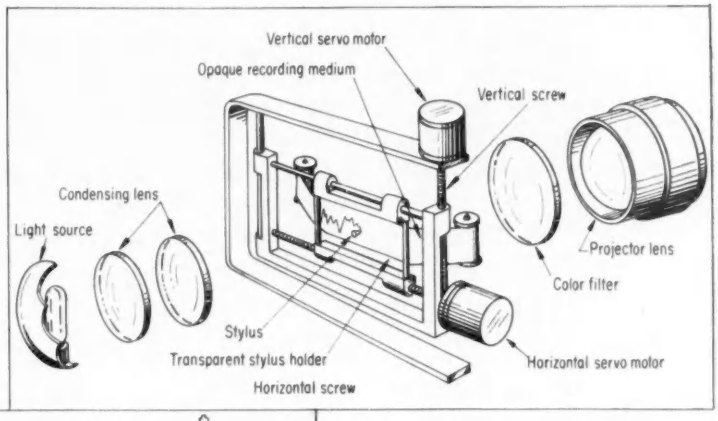


FIG. 2. TV projector built by General Precision Laboratory.

FIG. 3. Spot projector. Stylus removes opaque coating from transparent medium; transparent path is then projected on a screen.



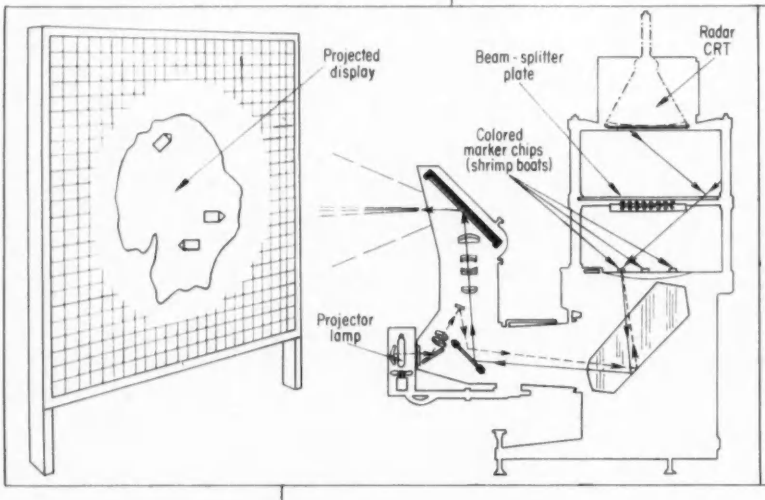


FIG. 4. Sky screen. Radar image is projected onto a beam splitter plate which reflects the image onto a horizontal plotting surface. Operator superimposes marker chip on plotting surface. Light from a projector lamp is reflected from the chip, projected onto the vertical surveillance screen.

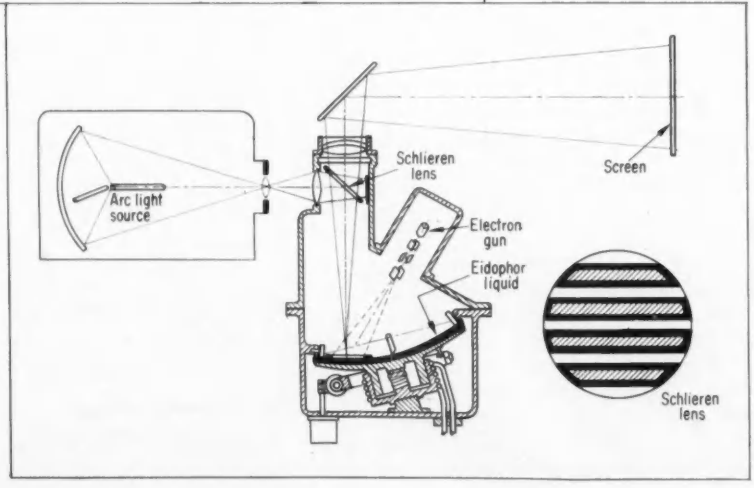


FIG. 5. Eidophor system. Electron gun bombarding liquid sets up ripples which reflect light from arc lamp in a pattern based on original signal. Passed through a Schlieren lens, reflections produce image of TV signal.

Schmidt system is less flexible, harder to adjust, and limits throw distances.

CRT image projectors

Schmidt optics have been used widely to enlarge directly the image formed by TV signals on a kinescope. Commercially available projectors can produce an image big enough for viewing by a theater audience. Here is a brief description of some typical projection equipments; all use Schmidt optics:

- General Precision Laboratory. TV Projector. Unit has a throw (distance from projector to screen) of 19 ft to produce an image 9 x 12 ft with a brightness of 2,500 ft-lamberts. At this brightness, resolution is 525 lines. Unit weighs 270 lb (18 x 66 x 22 in. in size), costs about $3,500 (Figure 2).
- Trad Electronics Corp. TV Projector. Similar in design to the GPL system, the Trad projector is said to provide an image of greater contrast. It has a special circuit which the manufacturer claims provides 30 percent more light output than competitive systems and automatically adjusts highlight and overall screen brilliance when low light values are received. Size of picture depends on throw; an 18 x 24-ft image is possible with a 60-ft throw.
- EMI projection technique. Developed by EMI Research Laboratories Ltd. (England), the system produces a 20-in. diameter display from a 3½-in. diameter long-persistence phosphor cathode ray tube. A new technique of fabricating the optical system (molding lenses from gelatins) eliminates the critical job of aligning cathode ray tube replacements. Display intensity is sufficient for viewing under an ambient light level of 0.1 ft-lamberts. A larger and brighter display could be built to magnify a 20-in. diameter CRT. Equipment costs about $1,150.
- DVST Projectors—Several companies have proposed an optical projection system to magnify the image of a direct viewing storage tube. Farnsworth (division of IT&T), for example, has built the Farnsworth Iatron Radar Projection indicator which was tested at Midway Airport in Chicago and Idlewild Airport in New York City. RCA has also built a DVST projector using Schmidt optics.

The relatively low resolution of the DVST and the tendency for intelligence to diffuse limits the usefulness of such a projection system. In general, the loss in resolution as brightness increases is greater in a DVST projector than in a TV projector. The one clear advantage of the DVST projector is its ability to present raw video in a one-stage display.

By combining a scan conversion tube (see "Techniques of Dynamic Display, Part I," CtE, February 1960, p. 100) and a TV projection system, it is possible to obtain both a magnified display of data and improved persistence characteristics of the image.

Spot projector

A different projection technique is that developed by Fenske, Fedrick, & Miller, for highly flexible multichannel X-Y plotters. A light source projects the transparent path created as a stylus removes an opaque coating from a transparent medium (see Figure 3). The stylus, mounted behind the recording material, is positioned horizontally and vertically by servomechanisms. Projection can be direct or rearward; the latter is more efficient. A colored filter colors the track for identification purposes.

Normally the recording medium is a glass plate on which an opaque-metallic coating has been deposited. One disadvantage of the system: the glass plates must be changed after each track.

If a self-healing material serves as the recording medium, the length of the track can be a function of the speed of the target (in an aircraft or missile tracking application); and the transparent holder supporting the stylus can be masked to show only a specific length of track. In such an application, the track does not represent the velocity of the target.

The plotters can be time-shared, too; self-healing film lends itself to such application. To do this, a solenoid automatically retracts the stylus from the film during the switching interval.

Performance characteristics: display can be projected to a size of 8 ft x 8 ft; response time is 2 sec max.; static accuracy, 0.15 percent of full scale.

Sky screen

Developed by Northrop Co., the sky screen projects the images of small marker chips, which are moved by an operator, onto a large translucent surveillance screen (Figure 4). Its Zoomar lens magnifies the image from 2.25 to 3.38 times with a throw of from 15 to 25 ft. High level ambient lighting does not detract from presentation. The chips are moved to correspond to targets in a radar display which is projected from a 16-in. PPI onto a horizontal surface.

Eidophor system

Large, 24 x 30-ft displays projected from television signals, are possible with the Eidophor system developed in Switzerland and being perfected by the General Electric Co. How it works is shown in Figure 5. The picture is generated by minute distortions of an oil coating on a mirror surface, distortions caused by bombardment from an electron gun. Light from an arc lamp is reflected from the surface of a spherical mirror through the slots of a schlieren lens (which is a vertically slotted mirror), then projected by a conventional optical system. The technique resembles somewhat the new thermoplastic recording technique unveiled by General Electric (CtE, Feb. 1960, p. 32), using the Eidophor liquid instead of a solid thermoplastic material.

Color can be made a part of the system. To do this, a color wheel is inserted into the path of the light beam from the arc lamp and rotated in synchronism with a field sequential TV picture system. Even with the color wheel, pictures are bright (about 10 ft-lamberts). Without the color wheel, pictures

are four to five times brighter.

Eidophor can generate a picture of greater resolution than the nominal 525 lines of standard television transmission. System costs about $50,000.

Film processors and projectors

One way of displaying a lot of information and recording the data in permanent form at the same time is to photograph it, process it rapidly, and then project the film onto a screen. Some of these devices do the entire operation in a few seconds.

Kenyon Instrument Co.'s Rapromatic 4000, for example, photographs data on 35-mm film which is then processed in two operations: developing and fixing. Two-operation technique prevents the plating out of free silver on processor parts, requires no toxic chemicals. Processing solutions are furnished in liquid form ready to use; each reload contains enough solution (8 oz) to process a full roll of film which is 200 ft long, or 3,200 pictures.

Top speed of the Kenyon equipment is about 30 frames per min. Exposure, development, and fixing each require at least 2 sec. The equipment projects the frame from the rear onto a built-in translucent screen. Normal displays are about 8 in. in diameter, but larger displays are possible by increasing the throw of the projection and the size of the screen.

Kelvin and Hughes has developed similar equipment. The K&H system has a three-part head in which exposure, development, and projection take place. Developing and fixing take place in the same chamber. Either a positive or a negative projection can be obtained.

Limiting factor on speed is the time for chemical development. A negative image requires 8 sec developing time; a positive, 24 sec. In producing a negative, minimum time for a complete cycle is 15 secs.

A dry film technique, proposed by IMP Engineering Corp., requires no chemical baths or sprays. A special film and a backing "blanket" in contact with the film contain the emulsion coatings to process and fix the photographs. Water triggers the action. After exposure to light, the film is developed and fixed; it can be projected as quickly as it can be transported from the exposure position to the projection position. The special film, either 16- or 35-mm could be designed for the light intensity of a CRT presentation.

Still another projection technique, studied by the Navy Electronics Laboratory, compresses the time of intelligence contained on several successive plan position indicator frames so that an observer can distinguish targets which might otherwise be lost in noise. Here is how the breadboard equipment

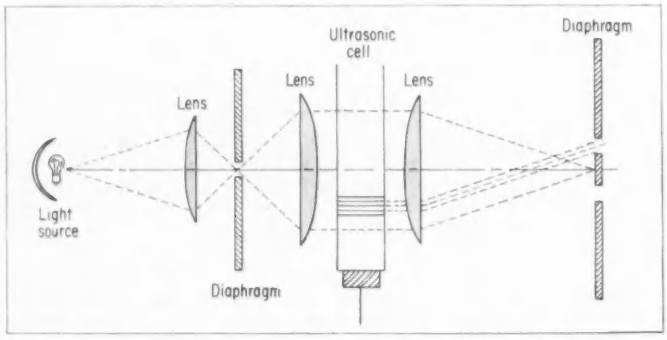


FIG. 6. Ultrasonic Light Modulator. Generation of ultrasonic wave in cell modulates light passing through the cell; varying frequency changes color; changing amplitude varies intensity.

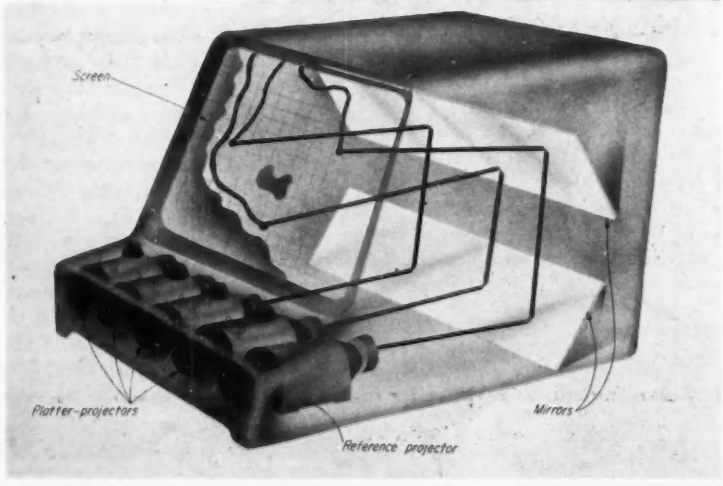


FIG. 7. Iconorama, three dimensional projector plotter.

operates. First, the PPI is photographed once each radar scan; then by means of a drum of prisms and a rotating light source, the most recently photographed 15 or 16 frames are scanned and projected as a motion picture. The scanning is continuous and repetitive so that the most recent sequence of frames is flashed repeatedly on the screen. The sequence of scanned frames is modified after each radar rotation by the addition of one new frame and the removal of the oldest.

Mirror and Filter Techniques

In a number of display techniques, composite images or effects are formed by the use of mirrors, filters, and light sources. The effects may be color, third dimension, or the addition of identifying information to a display.

Telechrome, Inc., has built the Trinoscope using two dichroic mirrors and three cathode ray tubes to present a color display. A separate CRT generates images in each primary color: red, green, and blue. The colors from the cathode ray tubes (or filters in front of white phosphor tubes) are blended and mixed by the dichroic mirrors which reflect or pass only specific colors. Built in sizes up to 20 in. for projection displays and 15 in. for direct view displays, the Trinoscope has resolution slightly better than can be obtained with a tri-color tube; brightness level is high—20 times that of a tri-color tube.

Another color display superimposes three separate color images produced by passing the light from three monochrome radar pictures through color filters. Developed by the Westinghouse Electric Corp., it obtains the three radar pictures either by painting three separate pictures on separate portions of a single 5-in., long persistence tube, or by painting a single picture on each of three similar 3-in. monochrome long persistence tubes. Color coding is accomplished by intensifying the appropriate picture or pictures. Range gating sorts the targets for color coding.

An unusual new technique uses ultrasonic waves to position the image. Developed by Fairchild Controls Corp., it has been called the Ultrasonic Light Modulator (Figure 6). A transparent liquid-filled cell, containing a quartz crystal to generate ultrasonic waves, acts as a variable diffraction grating to incident light. When the cell is excited, a point source of light is displaced from an aperture by an amount proportional to the amplitude of the ultrasonic excitation. By varying the frequency of the excitation, the cell can change the color of the image.

One disadvantage of the device: the output is not in a suitable form for viewing. The output must be recorded on moving film or sorted by some optical means into a raster suitable for viewing. Compared to a cathode ray tube display, the ultrasonic light modulator has these advantages: 1) resolution can be greater, 2) dynamic range is on the order of 100 to 1 (compared to 10 to 1 for CRT), 3) range of hue and intensity is continuously and linearly related to the frequency and amplitude of exciting signal, 4) maximum light intensity can be greater, 5) spot size can be smaller, 6) it requires no fail-safe features for electron gun or phosphors, and 7) it uses no operating voltages greater than 100 volts.

Third Dimension Techniques

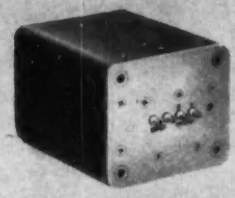
Techniques for presenting a third dimensional effect can be classified in three groups: 1) three-dimensional models, 2) two-dimensional representation of three-dimensional scenes (for example, isometric or perspective drawings, stereoscopy), and 3) coding techniques in which the third dimension is supplied by a symbolic representation on a two-dimensional display (example: numbers to indicate altitude on a display of aircraft position).

Bell Telephone Laboratories has suggested a cursor-coordinated display in which two two-dimensional displays are positioned vertically one above the other. The two displays correspond to the top view (X-Y) and front view (X-Z) of an engineering drawing. A vertical electronic cursor passing through both displays coordinates data, linking representatives of a given target by its common X coordinate.

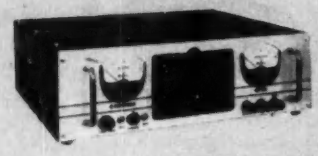
Stereoscopy is another method of obtaining a third dimensional effect. Stereoscopic techniques rely on the convergence characteristic of the eye. In a stereoscopic display, separate images are fed to each of the observer's eyes. The chief advantage of the stereoscopic effect is the natural appearance of the display. If numerous targets (such as radar blips) are displaced, the stereoscopic presentation is easier to interpret than one in which the third dimension is added in coded form.

There are some disadvantages, too. For example, eye strain is more pronounced since the observer has to focus his eyes for one distance and converge them for another. False clues such as noise and clutter tend to confuse the eyes. If goggles have to be worn, the observer has to keep his head erect or fixed. Stereoscopic displays appear to be seriously affected by ambient light. And stereoscopic presentation usually requires an elaborate (and costly) optical system.

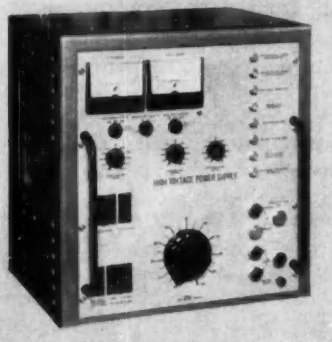
Typical of stereoscopic equipment is the display built by Fenske, Fedrick, & Miller. It uses two standard plotter-projectors for each target, positioned with their projection axes parallel and 2.75 in. apart. One set of servomechanisms positions the stylus holders of both plotters; an axis-servo effects partial horizontal convergence of the projected images. The plotter consists of a stylus which removes an opaque coating from a transparent vehicle and a light source and optical system to project the transparent path thus formed onto a screen. Properly oriented polaroid filters present the images as one to observers wearing special goggles.



Model QM6.3-.32. Miniature Transistorized Regulated D-C Supply features regulation to ±0.05% for combined line and load variations. This is one of more than 180 miniature component-type power packs offered by Sorensen. They include, in addition to highly regulated d-c supplies, dc-to-ac inverters and dc-to-dc converters.



Model Q12-15A. One of the 15 Sorensen Q Series high-precision transistorized low-voltage supplies, features voltage regulation to ±0.05% for combined line or load variations. Models for 6, 12, 28 vdc out, with power capacities up to approximately 240 watts. Similar QR Series features precision regulation with wide output voltage adjustment range. Two models: 0-75vdc at 2 amps max and 0-36vdc at 4 amps max.



Model 2150-5 (Control Section). This is just one of a tremendous variety of Sorensen high-voltage d-c supplies, high-voltage a-c and a-c/d-c testers, and electrostatic generators. Models completely cover the voltage range from 1000 to 600,000 volts. Power outputs range up to 60 kilowatts.

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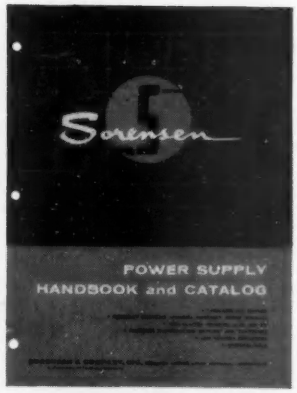

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Three Analog Computer Circuits for the Root Locus

This approach to analog solution of the root locus yields three practical circuits at different stages of its development, making possible static, semiautomatic, or automatic computer operation, with increasing equipment complexity.

GORDON CARDEN
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The characteristic equation of a closed-loop control system can be solved for its roots by equating the denominator of the closed-loop transfer function to zero. The typical unity feedback system with a transfer function $K\,G(s)/[1 + K\,G(s)]$ can thus be solved by setting $1 + K\,G(s) = 0$ and stating $G(s)$ in factored form:

$$K\frac{(s - s_z)}{(s - s_p)} = -1 \qquad (1)$$

which, since $G(s)$ is a complex variable, can be broken down further to

$$K\frac{|s - s_z|}{|s - s_p|} = 1 \qquad (2)$$

and

$$\phi_z - \phi_p = -(180 \pm n360) \text{ deg} \qquad (3)$$

where n is an integer. (s_z and s_p are the root values for s, which make their respective factors zero. A root in the numerator causes the fraction to approach zero and is called a "zero". A root in the denominator causes the fraction to approach infinity and is called a "pole".) A plot of Equation 2 on the s-plane ($s = \sigma + j\omega$) for all values of gain K is the locus of roots for the system. Figure 1 explains the meaning of Equation 3 on this plot. Since Equations 2 and 3 must both be satisfied, a simultaneous solution will produce the root locus.

The following develops an analog solution for the root locus in three stages: for static control, semiautomatic control, and automatic control. The circuits are shown for a system with one pole and one zero and are easily generalized for more complex systems.

From Figure 1,

$$\phi_z = \tan^{-1}\frac{\omega - \omega_z}{\sigma - \sigma_z} \qquad (4)$$

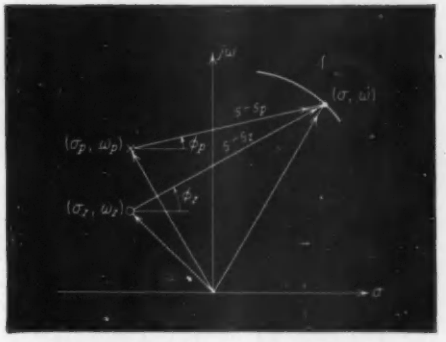

FIG. 1. The angles of Equation 3 on the s-plane.

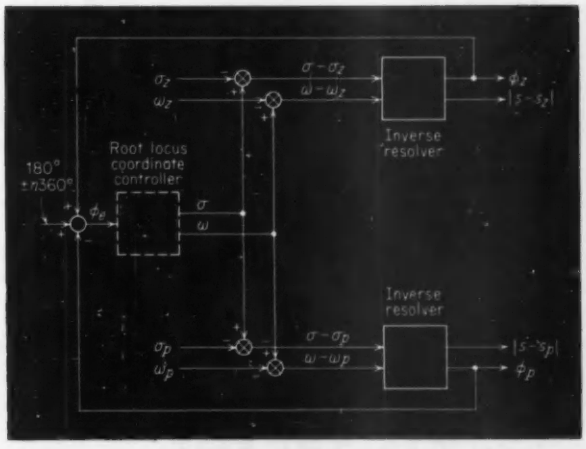

FIG. 2. Circuit for static solution of root locus problem. One resolver is needed for each zero or pole, shown here for simple case. The root locus controller in the dashed box is not necessary for the static solution as described in text.

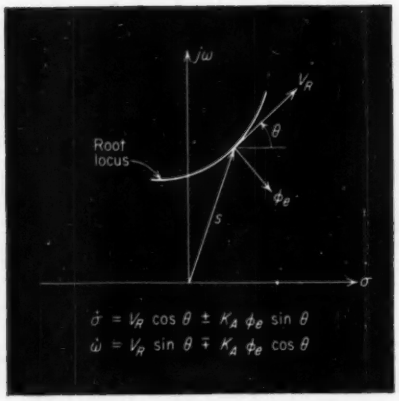

FIG. 3. Vector diagram showing constant velocity V_R of tip of s-vector along locus as used for automatic scanning of locus. Components of this velocity as rates of change along the s-plane axes are integrated to locus coordinates.

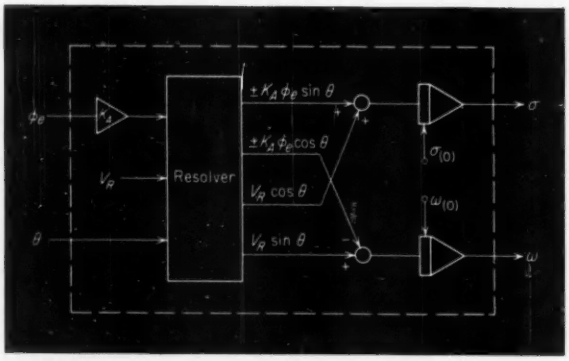

FIG. 4. Root locus coordinate controller. The input θ is manual in semiautomatic operation, is supplied by circuit of Figure 5 for automatic control.

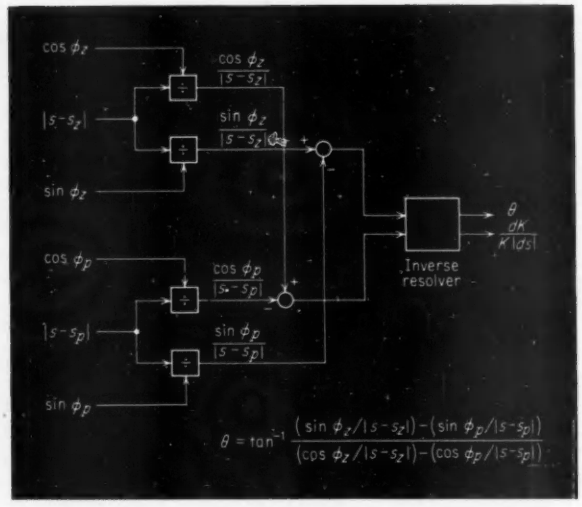

FIG. 5. Solution for θ can be made by circuit shown if resolvers used in static circuit of Figure 2 are three-cup type.

and $$\phi_p = \tan^{-1} \frac{\omega - \omega_p}{\sigma - \sigma_p} \qquad (5)$$

These angles, and thus Equation 3, can be solved on an analog computer by the circuit shown in Figure 2, which requires a resolver for each pole or zero. If the value of s does not satisfy the angle condition of Equation 3, then an angular error ϕ_e exists:

$$\phi_e = \phi_z - \phi_p + (180 \pm n360) \text{ deg} \qquad (6)$$

The angular error is the input to the locus coordinate controller of Figure 2, and the coordinates (σ and ω) of s are the outputs. This solution uses the least equipment of the three, but is the slowest and hardest to use. Potentiometers are fixed at values representing the coordinates of the poles and the zeros (σ_z, ω_z, σ_p, ω_p), and the root locus coordinates (σ and ω) are then varied so as to keep the error angle ϕ_e as near zero as possible. The gain K can be computed for any point on the locus from the resolver outputs and Equation 2. No equipment is needed in the coordinate controller block for static control as just described.

For semiautomatic or automatic control the coordinate controller must be instrumented and needs two other inputs that govern the rate of motion along the root locus curve. Figure 3 illustrates the coordinate change for a constant velocity V_R in the instantaneous direction of the locus θ. The vector value of the error angle ϕ_e has the direction of its maximum change with a differential displacement ds and is normal to the velocity vector. The instantaneous components of V_R along the s-plane axes are also given in Figure 3, with gain K_A adjusted for stable operation. Figure 4 is the circuit for the controller.

In the semiautomatic control solution the velocity V_R is set on a potentiometer at a low enough value to allow manual tracking of θ as estimated from previous locus measurements made in the static mode. The initial coordinate conditions on the locus are set on potentiometers for integrator initial conditions.

For completely automatic solution of the root locus, the velocity angle input θ can be computed as shown in Figure 5. The inputs are all available from the inverse resolvers of Figure 2 if three-cup resolvers are used. The computer can then be made to plot σ, ω, K, and ϕ_e as functions of time, with an average dynamic angular error of less than 0.2 deg.

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2. *SYNTHESIS OF FEEDBACK CONTROL SYSTEM BY PHASE-ANGLE LOCI*, Y. Chu, AIEE "Transactions", November 1952.
3. *CORRELATION BETWEEN ROOT-LOCUS AND TRANSIENT RESPONSE OF SAMPLED-DATA CONTROL SYSTEMS*, E. Jury, AIEE "Transactions", January 1956.

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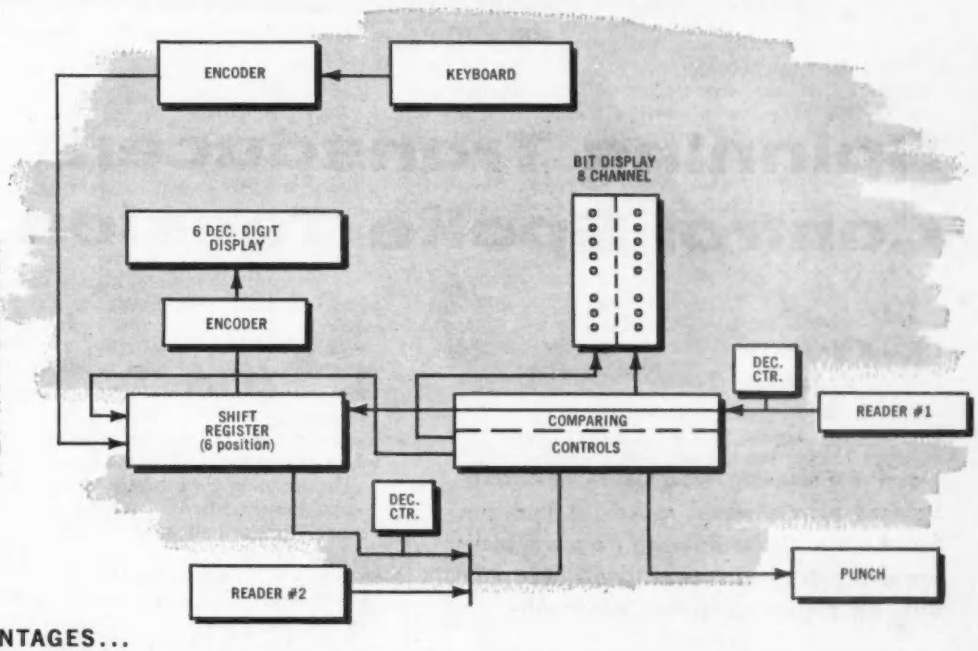

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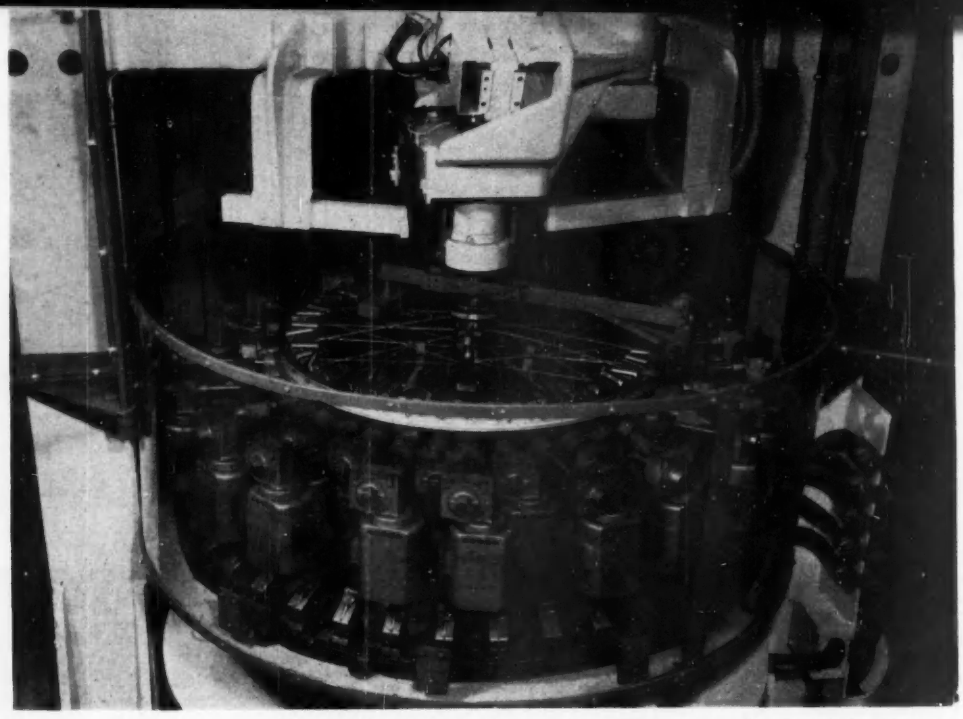


FIG. 1. Wheel truing machine correctly adjusts tension on 40 spokes within one minute.

Spinning Transducers Control Spoke Tension

DEREK BARLOW
Control Engineering (London)

Novel nut-torquing machine automatically tightens bicycle wheel spokes so that rim forms a true circle. Rotating magnetic pick-ups and averaging circuits supply necessary data for tensioning spokes individually.

The most critical operation in the assembly of wire bicycle wheels is running down the nuts that fasten the spokes to the rim. As the nuts are tightened, the spokes are put in tension. And indiscriminate tensioning can distort the rim from the desired circular shape and also warp or skew the wheel to one side or the other from the radial plane. When the operation is done manually, it is extremely difficult to put just enough stress on each spoke to produce a straight, truly circular wheel.

The wheel truing machine shown in Figure 1 was developed by Tube Investments Ltd. of England to do this operation automatically. It handles one wheel per minute, tightening each of the 40 spokes properly to hold the form of the rim to within plus or minus 0.03 in. of a perfect circle. Rotating magnetic pickups sense deviations of the rim and signal on-off commands to motor driven socket wrenches on each spoke. When the majority of spokes reach a preset value of tension, scanning stops and the wrenches disengage so that the wheel can be removed by the operator.

The torquing cycle begins when the wheel with the spokes loosely fitted is placed in the machine and clamped at the hub only. The first action of the machine is to lower the wheel so that the spokes engage the wrenches. Each of the 40 wrench assemblies consists of a fractional-hp motor driving a hexagonal socket through a reduction gear. The socket wrench rotates within a housing. There is a slot in both the housing and the socket, and when these slots are aligned, the spoke can enter the socket. This alignment is effected by means of a special two-segment commutator on the drive motor. When these segments are energized by cam-operated sequence switches, the motor inches around to the armature gap. When this position is reached, the motor stops and the slots are aligned. After entry of the spokes, the socket assembly slides forward along the spoke towards the tightening nipple at the rim, while a momentary impulse from the sequencing circuits rotates the spanner motor to ensure engagement.

Control system

If the wheel is straight and true, operation is simple: the drive motors run simultaneously until a preset value

of torque is reached. However, the real key to the value of the wheel truing machine is its ability to selectively energize each spoke's motor as required to correct distortion. This distortion is determined by means of a magnetic scanning arm, which is lowered over the wheel after the sockets are in place. The arm rotates at 240 rpm and carries two pickup coils, which are energized by 500-cps current. One coil determines wheel concentricity, and the other, mounted at right angles to the first, senses rim skewing in the radial plane.

The truing principle is based on comparing the location of each point on the rim against a reference circle and a reference plane. These references cannot be preset as far as diameter and spatial location are concerned, because manufacturing tolerances during the initial assembly are such that it would be impossible to make sufficient adjustment to bring each wheel into absolute agreement with a rigid set of references. Instead the approach is to measure the mean diameter and the mean deviation of the rim before torquing starts and to use these measurements as the references during the rest of the operation. Thus, finished wheels may vary minutely in diameter, but their form will approach that of a perfect circle, which is the primary objective.

Figure 2 shows the control circuit. Each sensing coil is connected in series opposition with a reference coil whose inductance is adjustable by means of a servo-controlled armature. These coils are connected as legs in two separate inductance bridges. Phase sensitive detectors measure the unbalance between the search and reference coil inductances, and the resulting error signals drive both the radial and skew reference amatures to their nulls. Long time constants in the servos average out diameter and skew variations and hold the armature positions constant during the head rotation. These positions are used as system references when tensioning.

When the reference servos have zeroed, the skew reference coil armature is locked. But the radial reference servo operates continuously because the radial diameter decreases during spoke tightening.

For adjustment the 40 spokes are divided into groups of four, each group consisting of a pair of spokes attached to the upper and a pair connected to the lower hub-flange. Relays apply the control signals to each pair through two 10-station selector switches coupled to the scanning head shaft. The spatial position of the energized switch wipers determines the socket group in operation. With a true wheel all sockets in the group are energized to raise the spoke tension. However, if the wheel is skewed, corrections are made by individually switching either the upper or lower socket pair in the group. The accompanying table shows the four sets of signals for the various error conditions.

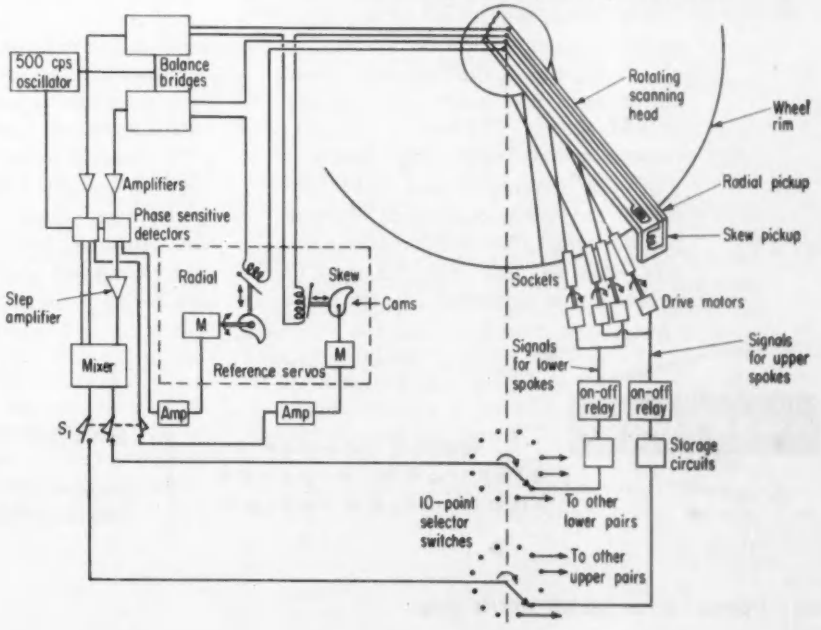
Signal Distribution for Various Types of Wheel Distortion

Type of Error	Signal to upper sockets	Signal to lower sockets
Top of rim skewed	OFF	ON
Bottom of rim skewed	ON	OFF
Under diameter	OFF	OFF
Over diameter	ON	ON

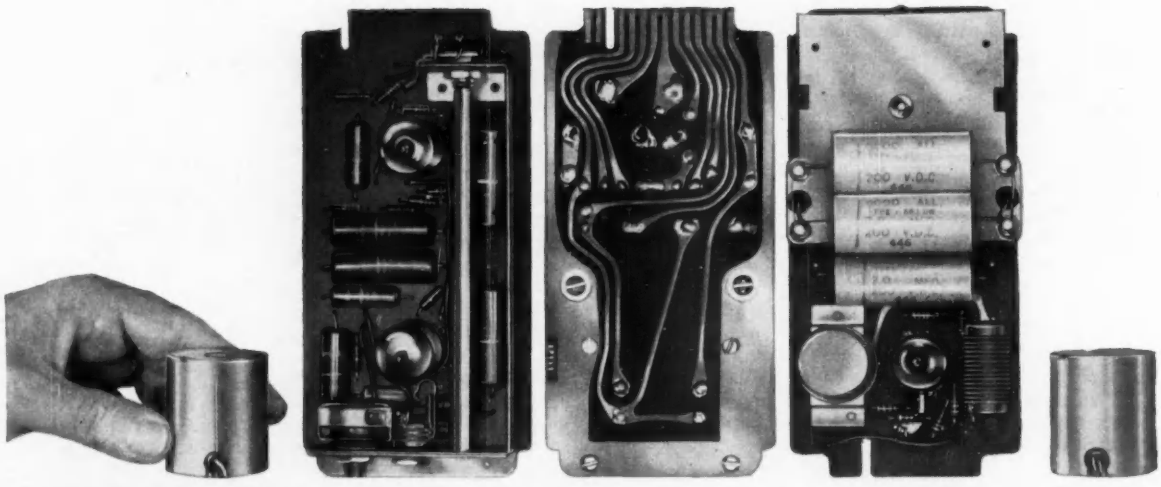
Because the socket wrench drive is nonreversible, the skew coil phase detector produces two outputs to increase the tension in either the upper or lower pairs of spokes. Radial detector error signals feed first a step amplifier and then mix with the skew signals in a diode network. Here, negative radial signals denoting an underdiameter wheel override the skew signals giving mixer output signals, thus deenergizing both the upper and lower socket sets. With correct or oversize rim diameter, zero output from the radial step amplifier unclamps the skew circuit shorting diodes and operates either the upper or lower socket sets according to which of the skew circuit outputs is energized.

The two selector switches coupled to the rotating scanning head feed the dc control signals four times a second to capacitor storage circuits associated with each socket pair. The capacitor potential operates a tube relay in the armature circuit of the socket motors. Under normal conditions with the wheel true, all 40 sockets run, tightening the spokes until a tension switch on each motor triggers at a preset value. Closing of each tension switch reduces the voltage across a dropout relay coil normally set to release when about 37 or 38 spokes reach the correct tension. Operation of the dropout relay stops the magnetic head rotation, switches in the slot alignment circuit, and initiates the socket disengagement prior to wheel removal.

FIG. 2. Schematic diagram of control circuit. Operation of Switch S_1 locks skew reference servo and connects control signals to spanner circuits.



CONTROL SYSTEMS RELIABILITY?



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Logger Keeps Track of Time Charges on Five Computers

Careful timekeeping is needed to charge computer running time against individual jobs. Author Piskor decribes a logging system that automatically keeps simultaneous program running time records for five IBM 704 computers. The system has been producing an average of 750 log cards per 24-hr day during the past 18 months.

JOSEPH PISKOR
United Aircraft Corp. Research Labs.

Since September 1958 an automatic logger has been keeping track of job times on five IBM 704 computers and producing punched log cards for accounting purposes. The logging system was designed, constructed, and installed by the Instrumentation Section of the Research Laboratories at United Aircraft Corp. Previously, a separate timekeeper was required for each shift and each computer to keep handwritten log sheets which then had to be translated into punched cards on a manual keypunch. Now the one logging system services all the computers and is run automatically from a central logging unit, Figure 1.

When a job is ready to be run on the computer, the dispatcher is notified and the job is listed together with its estimated running time. The dispatcher notifies the person who is to run the job in time to arrive at the computer with the job's program card deck before the preceding job is completed. Very little running time is lost between jobs; the running time of any job can therefore be determined from its starting time and the next starting time.

Figure 2 is a functional diagram of the logging system. The on-line printer associated with each computer serves as the connecting link with the logging unit. Programmed instructions from the computer connect the printer to the logger. The job data are inserted into the computer with a hand-punched card via the on-line card reader. These data are combined with a basic data group from the logging system memory and printed out. During this log printing cycle, the job data group from the computer core memory is transmitted to the buffer job memory at the logging unit for storage, and the connection between the printer and the logging unit is then teminated. Job memory and other logging system data are then punched into the log card.

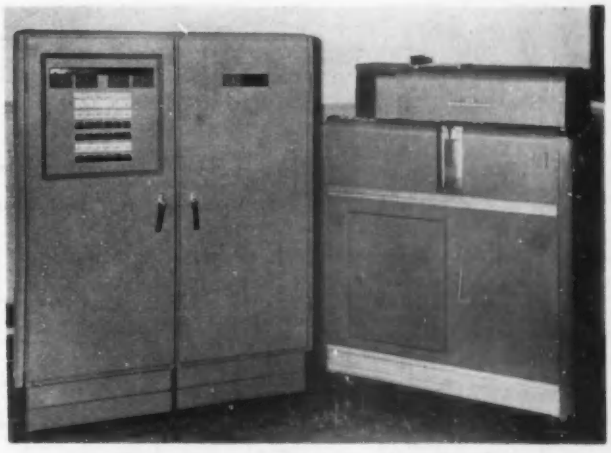

FIG. 1. Automatic logging unit and logging punch in the dispatcher's office. Rectangles on panel at upper left are master calendar clock indicators.

The basic data group consists of the date and time, a job classification code, the computer number, the operator's number, and a log-type code. A continue code is included if required, see Figure 3.

The date and time are supplied to all computers by a master calendar clock in the logging unit. The tape selector console of each 704 was modified to add a slave time indicator (Figure 4). The calendar clock is a group of stepping switches which represents the date and the time on a 24-hour basis. A pulse-

saver circuit prevents the calendar clock position from advancing during a logging cycle to insure that the same date and time digits will be both printed and punched for the start of a given job.

The relay memory in the logging unit is divided into several functional sections. The date-time memory senses the position of the calendar clock stepping switches and stores the data for presentation to the on-line printer, the logging punch, and the time indicators. Time is displayed to the last whole minute. The computer number and type for each computer are stored in a fixed memory section called the computer-log memory for presentation of this data to the on-line printers and the logging punch. The log-type memory receives and stores the signal requesting a log card and presents this signal as data to the logging punch only. Since the origin of this request determines the type of log card, this memory is cleared immediately after the log card is punched.

The operator log panel located at each computer is shown at the right in Figure 5. It includes an intercom for operator communication with the dispatcher and a keyboard for entering the operator's number into the logging unit memory. It also has indicators that show the state of the logging unit with respect to its particular computer. The row of buttons across the bottom permits the operator to enter his program classification code, which then produces an operator-correction log card.

Logging cycles

Three types of logging cycles are possible:

- The programmed-automatic cycle, which is the only one for which the program classification code is contained in the job data group, occurs when a computer job is started. It consists of a printing cycle followed by a punching cycle. The job data group is combined with the basic data group from the logging unit memory, printed on the on-line printer, transmitted to the computer core memory, and punched into a programmed-automatic log card.
- The alarm-stop cycle, which occurs after the computer has stopped for 30 sec due to a programmed stop such as completion of a job, a computer error,

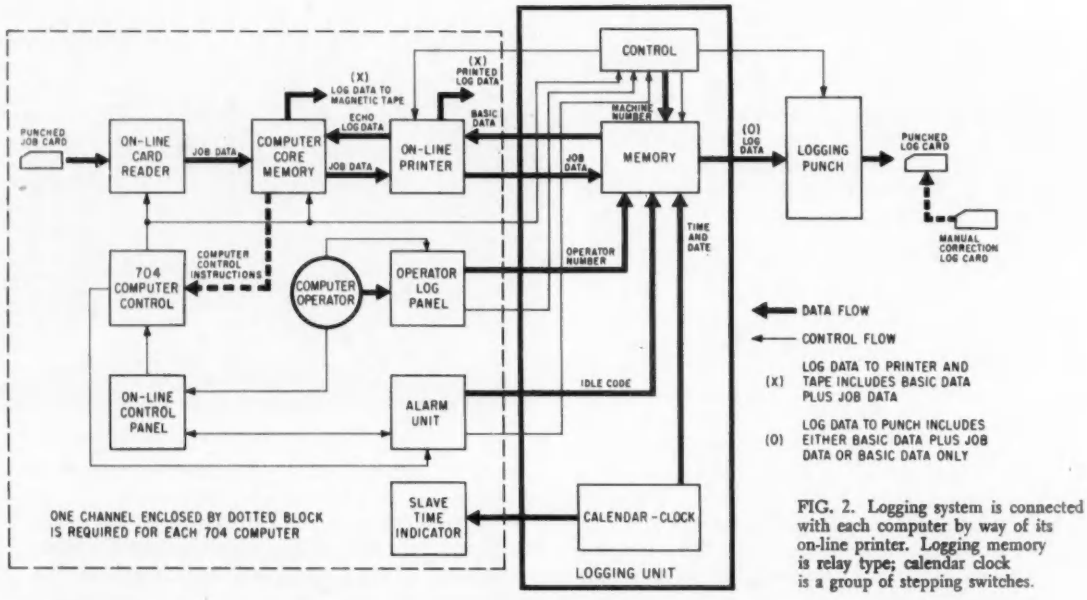

FIG. 2. Logging system is connected with each computer by way of its on-line printer. Logging memory is relay type; calendar clock is a group of stepping switches.

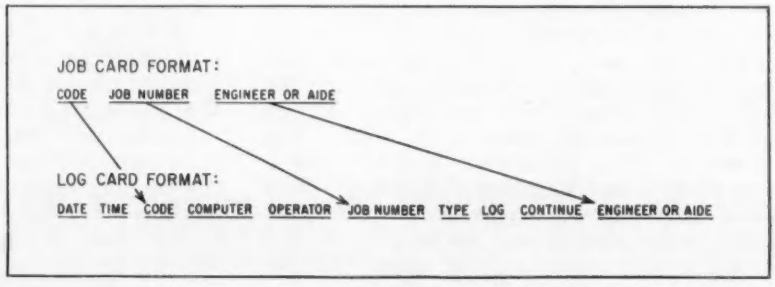

FIG. 3. Job cards are hand-punched with data shown, combined with basic data group entered via logging system to produce log card.

or a programmed selection of on-line or tape units that are either not ready or not connected. The alarm unit shown at the left in Figure 5 causes the starting time of the subsequent period of computer idleness to be punched into an alarm-stop card.

• The operator-correction cycle, which occurs only when the operator wishes to override the logging system with additional information or a correction.

As mentioned, the alarm unit stops the charging of time against a job 30 sec after the computer has stopped if another job is not immediately available or if the computer operator is out of the control area tending to off-line equipment. When this happens, the alarm unit lights an alarm indicator and rings a bell for several seconds to alert the operator.

After an alarm stop, the "continue" pushbutton on the alarm unit will reset the start and load controls to an effective condition and will set the continue memory. The very next log card for the same computer will contain the continue code, which has the effect of canceling the previous alarm-stop log card during accounting. Pressing the "continue" pushbutton during the 30-sec countdown before the alarm-stop condition occurs will freeze the countdown and prevent the alarm-stop from occurring.

After an alarm-stop, the "clear" pushbutton on the alarm unit clears the program in the computer and allows the loading of the next job. The alarm unit is reset automatically whenever the computer starts.

The program classification code in the log card records the kind of job run on the computer, the reason for subsequent computer idleness, or a correction overriding the code for the kind of job that had been started. A job is normally run with a production job code, a program checkout code, an experimental program code, or an IBM diagnostic program checkout code. Corrections are indicated by either a computer error code or a program error code. Subsequent computer idleness is indicated by an idle (no work) code; shutdown code; power failure code; or by a scheduled, an unscheduled, or an off-shift maintenance code.

Since a logging request can be initiated by a computer, the alarm unit, or the operator, and several computers are serviced by one logging unit, priority-shared circuits are necessary to direct the traffic. If the logging system is in use when a computer connects its printer to the logging unit, the printer stops and waits for its turn as determined by the priority circuits. The printer is disabled during this usually short waiting period. When a logging request from a second computer is received while another is being executed, the first request is executed completely before the second is filled. When requests from two computers are received simultaneously, the one with the lower computer number is executed first.

The logging system must cope with races in a predetermined manner so as not to reduce appreciably the effectiveness of the system. A race is a condition when two different logging requests for the same computer are received simultaneously or in such rapid succession that the first request has not been completely executed before the arrival of the second. Races are very unusual but do occur. They must be handled so as to be nondestructive, nonjamming, and self-clearing. Furthermore, the job data group is available to the computer at only one time and cannot be dropped, though its use may be delayed. Races are treated as follows:

1a. Programmed-automatic request followed by operator-correction request: the operator-correction request is canceled and the programmed-automatic request continued. (Operator's request is so late that the next job has started. Operator can prepare a manual correction card and add it to the log card deck, Figure 2.)

b. Operator-correction followed by a programmed-automatic request: the programmed-automatic request must wait, but both will be executed.

2a. Programmed-automatic request followed by an alarm-stop request: the alarm-stop request is canceled and only the programmed-automatic request executed.

b. Alarm-stop request followed by programmed-automatic request: the programmed-automatic request must wait, but both will be executed.

3a. Operator-correction request followed by alarm-stop request: the alarm-stop request is canceled and the operator-correction request executed.

b. Alarm-stop request followed by programmed-tion request: the operator-correction request is canceled and only the alarm-stop request executed. (Again the operator's request is too late, since the 30-sec countdown is completed. The operator can initiate his request again and it will then be executed.)

FIG. 4. General view of IBM 704 operating console shows slave time indicator added to tape selector console (just over operator's head) with alarm unit and operator's log panel at far right.

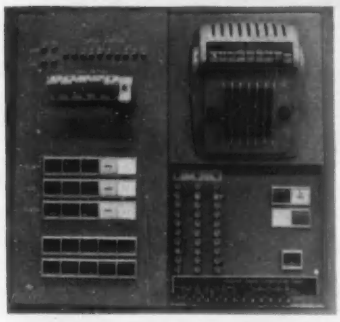

FIG. 5. Logging system alarm unit (left panel) and operator's log panel (right) installed at each computer.

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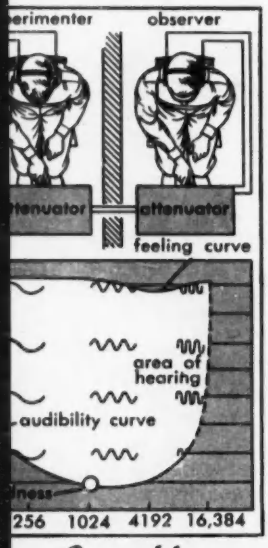

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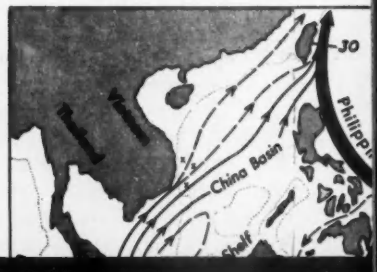

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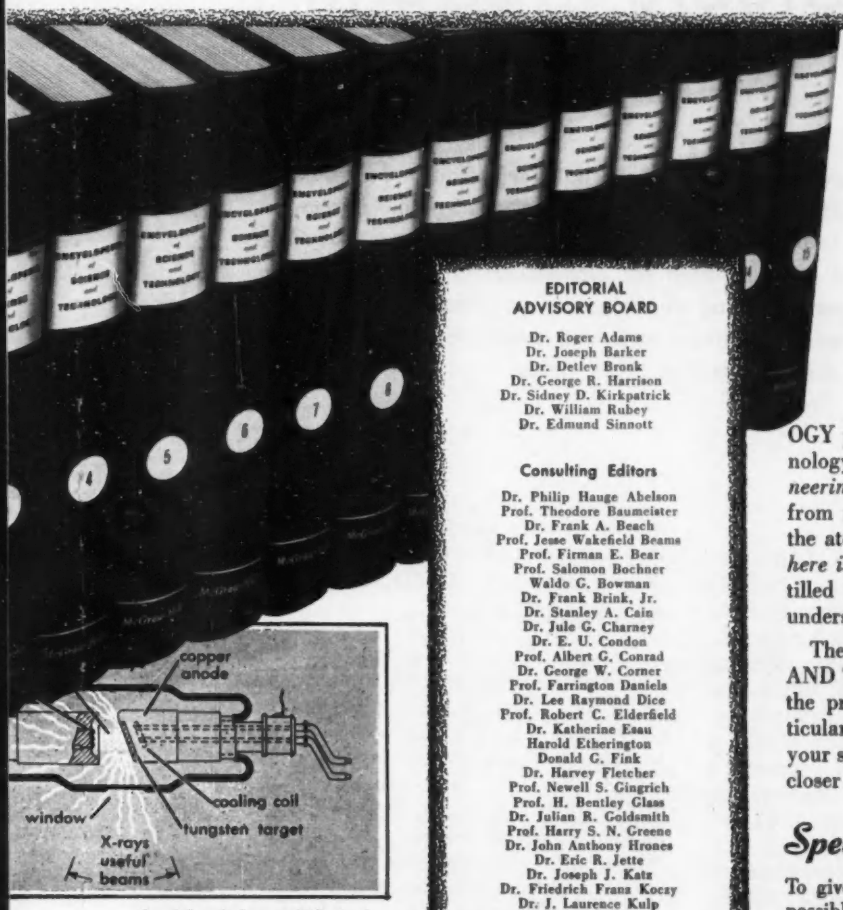

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Novel Caging Scheme Makes Versatile Stable Platform

THE GIST: A technique developed in the field of inertial navigation and verified by the performance of feasibility models uses a novel feedback scheme in conjunction with a hermetically-sealed integrating gyro. It provides continuous monitoring of, and automatic compensation for, unbalance torques. It also permits simultaneous caging and uncaging of the gyro input and gimbal axes in an extremely simple manner and without switching transients. One device based on this technique was used for testing other gyros.

M. SELVIN
Bell Telephone Laboratories

A basic principle of mechanics states that the rate of change of angular momentum of a body equals the applied torque. With no external torque, angular momentum is conserved and its rate of change equals zero. In the special case of a symmetrical rigid body rotating about its axis of symmetry, angular momentum is simply the product of its moment of inertia and its spin angular velocity.

If a gyro spin motor is built so as to maximize its moment of inertia and is rotated at high velocity, its spin axis will tend to remain "fixed to the stars", i.e., independent of the earth's polar rotation. To measure the extent of this independence it is necessary to isolate the spin motor rotationally from all external torques. Very low friction bearings serve this purpose.

For a gyroscope the equation relating torque to angular momentum may be written as follows:

$$\bar{T} = \bar{\Omega} \times \bar{H}$$

where T represents the applied torque, H the angular momentum, Ω the precessional angular velocity, and $\times$ the cross product of two vectors.

This equation is reversible, i.e., a torque input results in a precessional output, and an angular velocity input results in a torque output. The torque, precessional velocity, and angular momentum vectors are mutually perpendicular, and Equation 1 defines the behavior of a minimum gyro—one having spin angular momentum sufficient to create space fixity and a degree of freedom perpendicular to its spin axis so that torques or rates can be measured.

Gyro functions

Figure 1 shows a simplified sketch of a single-degree-of-freedom gyro with spring restraint. A rate about its sensitive input axis causes a torque about the gimbal axis. The spring deflects to balance the torque, and this deflection provides an accurate measure of input rate. This can be read directly on a graduated dial or via an electrical pickoff. Viscous damping prevents sustained oscillations. Gyros of this type are called rate gyros and are commonly used as rate-of-turn indicators on aircraft.

Figure 2 shows a two-degree-of-freedom gyro used as a vertical gyro. Bearings on the outer gimbal axis are fixed to the case, and the case is fixed to the vehicle. As the vehicle maneuvers, the case may leave the vertical in either of two ways: by rolling about the outer gimbal axis or by pitching about the inner gimbal axis.

In a rolling maneuver, bearing friction drags the outer gimbal a small amount in the direction of the roll. This motion sets up a gyro precessional torque about the inner gimbal axis. Motion of the inner gimbal then generates a restoring torque about the outer gimbal axis. In a pitching maneuver a similar situation exists, and the outer gimbal stabilizes bearing drag on the inner gimbal.

The two-degree-of-freedom gyro can be implemented to simultaneously measure angular displacement about two mutually perpendicular axes. This is the type of gyro used in aircraft either as a vertical

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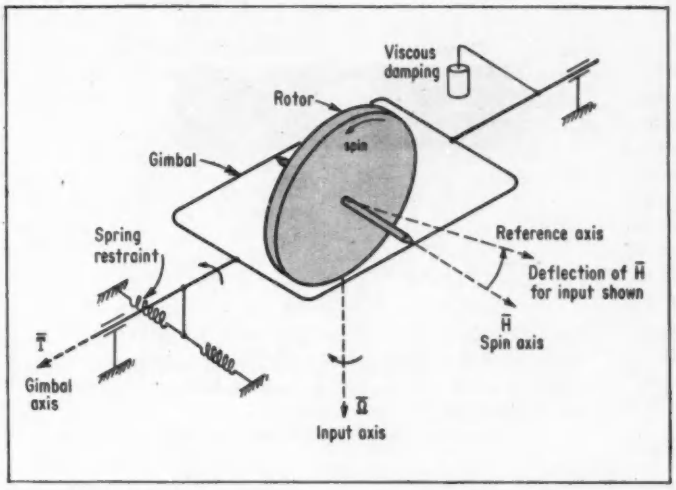


FIG. 1. Simple rate gyro with a single degree of freedom.

BASIC GYRO CONFIGURATIONS

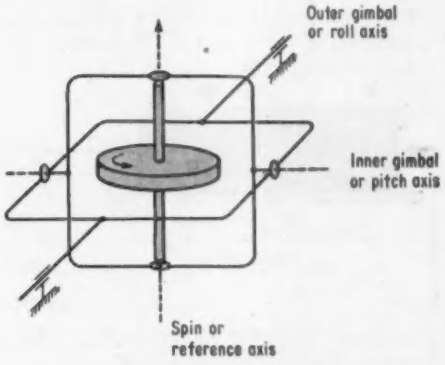


FIG. 2. Two-degree-of-freedom gyro oriented for use as a vertical gyro.

gyro oriented as shown in Figure 2 or, with its spin axis horizontal, as a directional gyro.

The gyros in Figures 1 and 2 are self-contained units; they not only sense motion, but also have the "muscle" to do something about it. This combination of sensing and torque capability in the same unit imposes a serious limitation on precision and has led to the design of instruments in which these functions have been separated. One of the most fruitful developments based on this separation principle was the HIG (hermetically-sealed integrating gyro) developed at MIT. This is a single-axis gyro (no spring restraint) with its gimbal neutrally floated in a viscous fluid. Because of its integrating properties (almost infinite resolution) and the low friction levels inherent with flotation, this instrument can maintain its reference with exceptional stability. The design, however, makes it necessary to have a servo associated with each gyro.

Although gyros with two degrees of freedom are more versatile than single-axis instruments, they are fundamentally more difficult to build. In spite of the current effort to overcome design and manufacturing problems, it still appears that the precision with which an adequately instrumented single-axis gyro can maintain its inertial reference is without peer. For this reason, the following deals only with applications in which the HIG is used as the main sensing unit.

Rate sensing servoloop

Figure 3 shows a schematic of a HIG used in a rate sensing or caging loop. If a rate is applied to its input axis, the gyro tries to precess about the gimbal or output axis. A microsyn pickoff senses any gimbal displacement and immediately drives current through a torque generator to null the gimbal. Since this torque is proportional to input rate, torquer current is an accurate measure of input rate. With this setup it has proved practical to measure the earth's rate. As a rather extreme extension of this scheme, if the gyro input axis is held horizontal and the case rotated about the vertical axis, torquer current will drop to

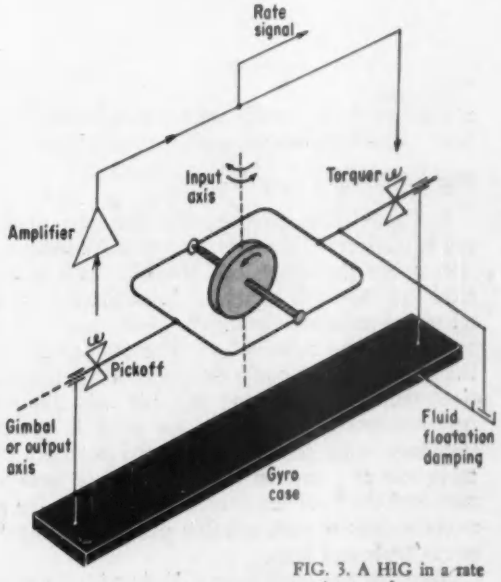


FIG. 3. A HIG in a rate sensing servoloop.

SINGLE-AXIS STABLE PLATFORMS

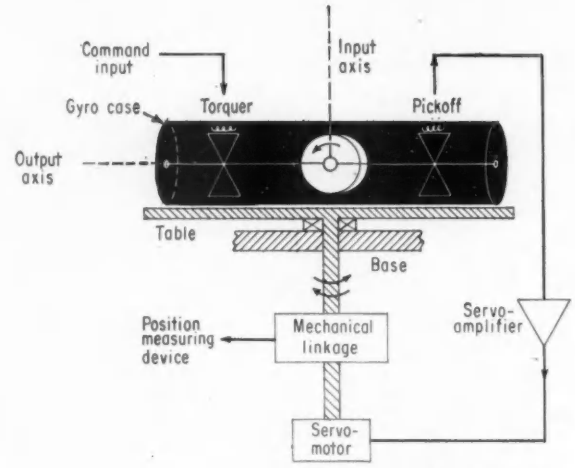


FIG. 4. Platform without caging loop.

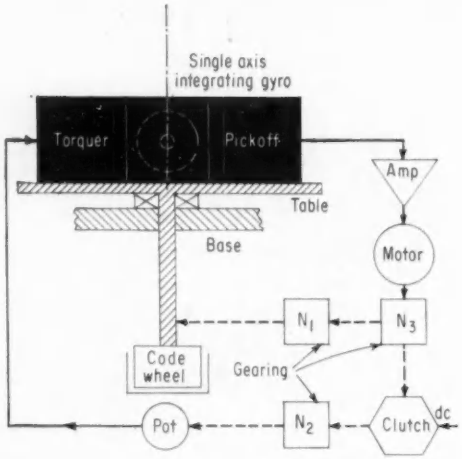


FIG. 5. Caging scheme for platform in Figure 4.

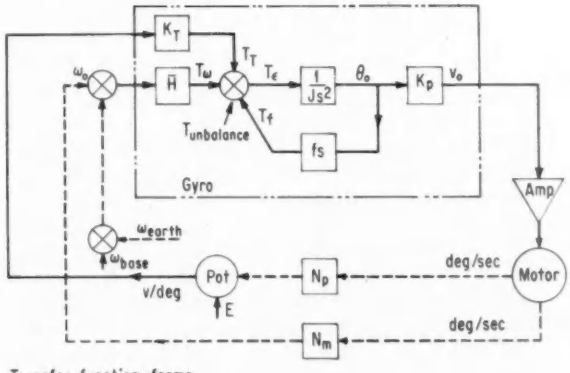


FIG. 6. Block diagram and transfer functions of table and caging loop.

Transfer function forms

For servo table: $\frac{T_\omega}{T_\epsilon} = \frac{A}{s(1+t_m s)(1+t_g s)}$

For caging loop: $\frac{T_T}{T_\epsilon} = \frac{B+As}{s^2(1+t_m s)(1+t_g s)}$

zero when the input axis reaches an east-west orientation. This takes an unusually accurate gyro.

Stable platform operation

In Figure 4 the gyro serves as part of a single-axis stable platform. If a rate is applied by rotating the base about the input axis, the table and gyro case tend to follow this rotation. Immediately, the pickoff senses precession about the gimbal axis and sends a signal to the servomotor. The servomotor drives the table in the opposite direction of the input rotation, thereby maintaining the spin axis orientation. Any component located on the table is, therefore, stabilized with respect to external rotation. The table acts as a mechanical integrator of base input rate, and the total base angular change can be accurately measured with suitable pickoffs mounted between table and base.

Note that the table cannot distinguish between an input rate and a gimbal axis torque. Any gyro unbalance acts as a false rate input and, as the table integrates this rate with respect to time, it produces a continuously increasing position error.

One novel method of using this gyro is shown in Figure 5. Here the single-axis stable platform constitutes the major portion of the system. In addition, an electromagnetic clutch and a potentiometer have been mechanically coupled to the sensitive table axis. In the caged position the clutch acts as a positive mechanical drive, and the potentiometer rotates with the sensitive axis causing current to flow through the torquer winding. At uncage the clutch is disengaged, and the potentiometer shaft is locked in its caged position independent of any further rotation of the input axis. Figure 6 shows a block diagram of the servo loops together with transfer functions for the two modes of system operation.

Assume initially that the system is stable, and

consider only the steady state performance of the caged device. If ϕ represents displacement of the input axis with respect to space, and θ the gimbal angle, the torques acting on the gimbal axis are blanced as follows:

$$\underset{\text{gyroscopic}}{-H\phi} + \underset{\substack{\text{caging}\\\text{pot}}}{K_T\phi} = \underset{\substack{\text{gimbal}\\\text{acceleration}}}{J\theta} + \underset{\substack{\text{gimbal}\\\text{damping}}}{f\dot{\theta}} + T_{unbalance} \qquad (2)$$

Here gimbal positional spring restraint is assumed negligible and $\dot{\phi}$ equals the total angular velocity about the input axis (i.e., $\omega_{earth} + \omega_{base}$). If the base velocity is zero, the steady state solution forces all derivatives of θ to zero so that Equation 2 becomes

$$K_T\phi = T_{unbalance} + H\omega_{earth} \qquad (3)$$

Therefore, at equilibrium both ϕ and θ equal zero. The gimbal axis is nulled and the sensitive axis is stationary at some arbitrary position. After initial caging and zeroing of the sensitive axis, if the unbalance torques vary, the sensitive axis will be displaced. It has been shown, however, that this motion can be held to about 2 sec of arc. Note that the caging potentiometer wiper voltage provides a *precise* and *continuous* measurement of both gyro *bias torques* and the $H\omega_{earth}$ torque and simultaneously keeps the single-axis table *earthbound*.

An examination of the open-loop transfer function leads to a similar conclusion. The servo has a second-order pole at the origin. This means that, for a constant positional or constant velocity input about the sensitive axis, the idealized servo is errorless. The gyro gimbal axis will remain nulled for both types of inputs, but for a constant velocity input, the sensitive axis will have a positional displacement with respect to the command input.

Stability of this system is a little unusual. If the mechanical connection between gyro and table is opened, the caging loop becomes unstable. This is especially true since the above transfer function analysis is oversimplified. The caging potentiometer introduces another integration stage to the servoloop and is a highly *destabilizing* force. Artificial compensation networks would be needed to stabilize the caging loop. With a rigid connection between gyro and table, however, the single-axis platform serves an important auxiliary function in addition to its main function of spatial stabilization. Because the caging loop is a *positional* feedback system and the single-axis table responds to *velocity*, the platform provides derivative feedback for the caging loop. Interrelation of the loops thus benefits system stability.

Note that precessional torque of the gyro has been neglected in this analysis. This is justified by the fact that, in the actual model, the gyro is highly damped and gearing reduces the effectiveness of this stabilizing torque. In other applications a direct drive has been combined with a low-damped gyro, but the pros and cons of this implementation will not be considered here.

In essence then, the single-axis table in Figure 5 is a minor loop within the caging loop. In cage the potentiometer continuously measures and compensates for earth rate and gyro unbalance torques. Uncaging disconnects and locks the shaft of the caging pot which then "remembers" and provides a constant compensation based on earth rate and gyro torques existing at the time of uncaging. Since the gimbal axis has been at null, no transient is inserted into the single-axis table. During cage the table prevents oscillations in the caging loop. At uncage the platform is instantly ready to measure and stabilize any additional mechanical rotations.

PUTTING THE CAGING SCHEME TO USE

Inertial guidance

In recent years great emphasis has been placed on aircraft and missile guidance without the use of any external reference. This requires an extremely stable frame of reference that can be mounted in the vehicle. The four-gimbal structure in Figure 7 is designed to serve this purpose. Three mutually perpendicular gyros are mounted on a platform which is isolated from the vehicle by three degrees of rotational freedom. The outer roll gimbal is shown only for completeness. In straight, level flight, it is redundant with the inner roll gimbal. Its function, the prevention of gimbal lock, is not germane to this discussion. Each gyro and associated gimbal operates to stabilize an axis of the platform. Accelerometers mounted on the platform measure the linear motion of the vehicle (in the known coordinate system), and gimbal pickoffs meas-

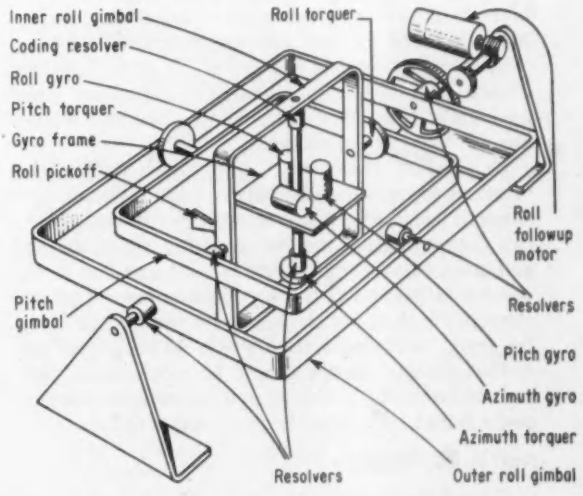


FIG. 7. Gimbal orientation diagram of stable platform used for inertial navigation.

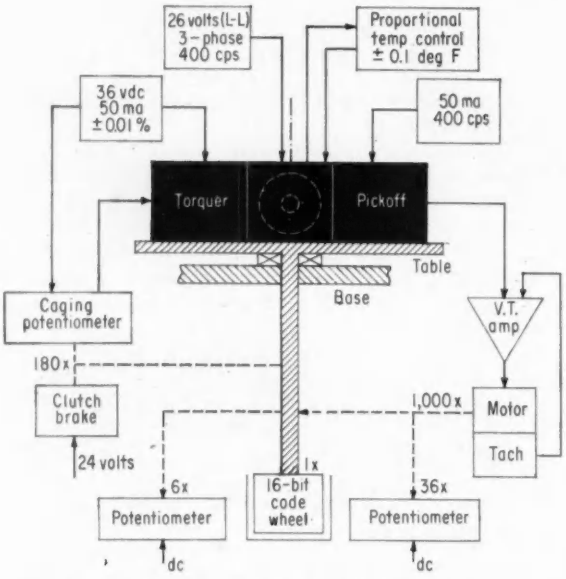


FIG. 8. Feasibility model of an azimuth reference system.

ure its attitude. With the aid of a computer, information provided by such a system can be used to solve any navigational problem.

In the absence of external inputs, the platform remains fixed in space and provides one satisfactory means of navigation. As the vehicle travels, however, the angular orientation of the platform varies with respect to the earth's axis. Another common mode of navigation is to keep the platform axis continuously aligned with the earth's axis (local vertical). Rotation of the earth causes a relative motion at the equator equivalent to a 900-knot aircraft moving with respect to a stationary earth. The caging scheme described above generates this bias rate automatically. Error torque compensation is developed on the ground during initial alignment. At take-off, the system is uncaged. This does not eliminate the need for feedback signals from the accelerometers which torque the gyros. It does, however, reduce the maximum signal the computer must generate. Note that the scheme does not require any special gyro orientation.

In practice, there may be an unavoidable delay of weeks or even months between the time the gyro is tested and the time it is actually put to use. With this caging scheme, the gyro is continuously checked and compensated and, when put into service, is the same as if it just left the production line. The caging scheme does not, however, improve precision of the gyro. After uncaging there is no additional correction for any change caused by acceleration, thermal environment, shock, or gyro uncertainty torques, performance still depends on gyro quality.

Lab instrumentation

One of the most significant measures of gyro quality is its drift rate or equivalent gimbal axis torque. This torque is commonly measured by using a gimbal pickoff and torquer to drive the gimbal to its null position. Earth's rate can be eliminated by calculation or gyro orientation, but the precision of measurement is limited by gimbal jitter and amplifier noise. Drift runs are usually made on a single-axis table. Based on repeated drift runs, results might be listed as follows:

average drift rate	9 deg per hr
earth's rate	10.5 deg per hr
bias drift rate	1.5 deg per hr
random uncertainty	0.05 deg per hr

With the suggested caging technique, error torques can be read directly from the caging potentiometer (locked if necessary). The only limit on measurement accuracy appears to be imposed by the external meters. With optical indicators the nonpredictable component of gyro and servo performance can be measured directly. The bias value of gyro unbalance can be compensated for by using a manually set current value, but it becomes difficult to maintain the correct value for any length of time.

One special case

Figure 8 shows a schematic of a feasibility model developed to monitor the earth's shift about a vertical axis in an earthquake area. A preliminary study of the problem indicated that the earth tremors might last for 30 sec and that reflected ground waves might exist a few minutes later.

The figure also shows that repeated cage-uncage operation of the device algebraically adds each successive mechanical input.

While this particular unit has not yet been field tested, the following laboratory results should be of interest to a systems designer:

- Its single-axis table has a bandwith of 12 cps.
- Its caging servo holds the table earthbound to within 1 sec of arc. (The gyro had to be operated for a full 24 hr before this degree of performance could be obtained.)
- Clutch-declutch error appeared to be negligible. (Even with a Farrand autocollimating telescope, having a resolution of 1 sec of arc, it was impossible at times to tell if the system was uncaged; at times the system would quiver and then stabilize with no measurable error.)
- With the system subjected to uncalibrated hammer blows, error was no greater than 5 sec of arc after a 10-sec interval. Rotating the base through 4 deg in 0.5 sec produced a maximum error of 10 sec of arc; if the base was rotated slowly, it was difficult to notice any motion at all.
- Overnight runs yielded average drift rates of from 0.04 to 0.7 deg per hr.
- On production models, the gyro and code wheel will be direct-coupled so that gearing will introduce no error; although gearing was not mandatory on the laboratory model, it did help to simplify the design problem.

Updating Process Instrument Costs

JOHN W. BERNARD
The Dow Chemical Co.

Once a process construction project has been studied long enough to determine the instrumentation needed to control the plant, a fairly accurate cost estimate—based on the *installed* costs of typical instrument systems—may be prepared quickly from such cost data as that shown in the accompanying table.

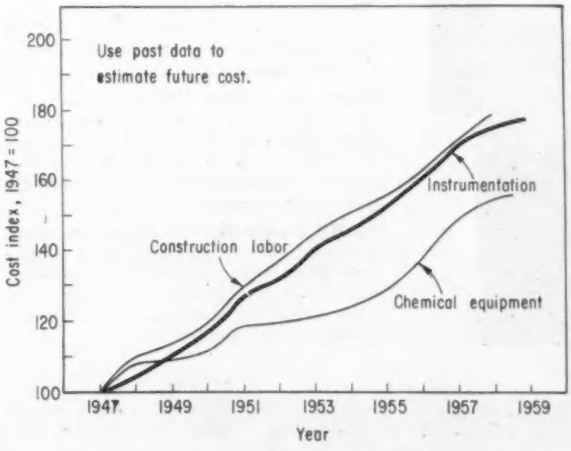
This table reflects changes in costs occurring since the summer of 1957, as reported by the author in "Three Ways to Estimate Instrumentation Costs of Process Plants", CONTROL ENGINEERING, February 1958. The present table includes installed costs as of December 1959. In general, most costs have risen, but several prices did decrease, due either to an actual price reduction or to a change in the way Dow normally specifies the particular instrument.

The installed cost includes 60 percent added to purchased cost for such items as labor and material for mounting, instrument piping, wiring, and painting. Note also that system costs include the price of a 1-in. cast iron control valve. The table lists, however, the cost of valves of other sizes and materials, so that if a 3-in. alloy is to be used, the added cost is then:

$$(\$480 - \$220) + (2 \times \$400) = \$1,060$$

Estimated future costs

An estimating error can occur even when the estimate does detail all items, as taken from the table, if future prices are not anticipated for instruments to be purchased at a later date. The information in the figure can be used to extrapolate future costs into present-day estimates.



INSTALLED COSTS OF INSTRUMENT ITEMS AND SYSTEMS

Instrument item or system	Total*** installed cost, $
Alarms	$100 plus switching items cost
Ammeter system	187
FI, flow indicator	232
FG, flow gage glass	80
FR, flow recording system	1,060
FRC, flow recording controller system*	1,790
FS, flow switch	176
LC, level control system*	642
LG, level gage glass	80
LI, level indicator system	540
LR, level recorder system	885
LRC, level recording controller system*	1,620
LS, level switch	230
pHI, pH indicator system	954
pHR, pH recorder system	2,190
pHRC, pH recording controller system*	2,920
PC, pressure controller	205
PI, pressure indicator (standard)	32
PI, pressure indicator (chem. type)	128
PR, pressure recorder system	670
PRC, pressure recording controller system*	1,400
PS, pressure switch (standard)	40
PS, pressure switch (special)	160
SI, speed indicator system	384
TC, temperature controller	222
TI, temperature indicator	30
TI, temperature ind cator, multipoint (24)	2,500
TIS, temperature indicating switch system**	492
TR, temperature recorder, single point	1,300
TR, temperature recorder, multipoint (12)	2,630
TRC, temperature recording controller system*	2,020
ADD FOR:	
Valve, pneumatic (cast iron)	$220+$160/in. over 1 in.
Valve, pneumatic (steel)	$320+$200/in. over 1 in.
Valve, pneumatic (alloy)	$480+$400/in. over 1 in.
Valve positioner	160
Valve, solenoid	32
Air drier	28/SCFM
Rate action	55
Pneumatic set-point	170

* With 1-in. cast iron control valve with pneumatic actuator, no positioner
** With solenoid valve
*** Based on instrument costs in December 1959, plus 60 percent for installation

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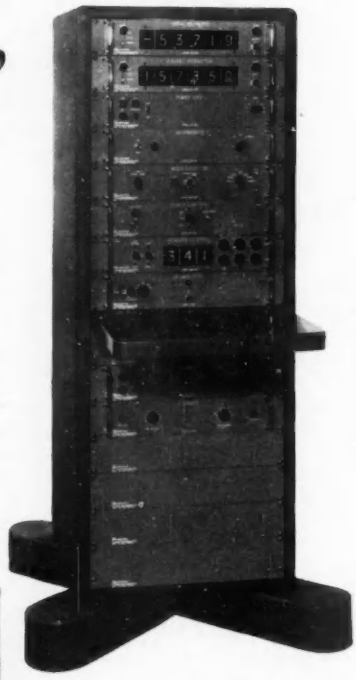

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The MH is not a new relay.

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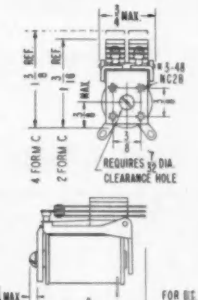
A multiple choice of terminations add to the MH's versatility. This relay, for example, can be adapted for printed circuits, furnished with taper tabs or a long list of other terminals. Get all the facts by calling your nearest P&B sales engineer today.



MH ENGINEERING DATA

GENERAL:

Breakdown Voltage: 500 volts RMS between all elements.

Ambient Temperatures: −45° C to +85° C. (−65° C to +125° C on special order.)

Shock: 30g on special order.

Vibration: 10g from 55 to 500 cps.; .065" max. excursions from 10 to 55 cps. on special order.

Weight: 2½ ozs. max. (open relay)

Terminals: Pierced solder lugs; special lugs for printed circuits, taper tab (AMP #78).

CONTACTS:

Arrangements: Up to 9 springs per stack.

Material: ⅛" silver standard: Palladium or gold alloy also available.

Load: Dry circuits to 5 amps @ 115V AC res.

COILS:

Resistance: 22,000 ohms max.

Power: 100 mw per movable min. to 4 watts at 25° C max. (200 mw min. to meet max. shock/vibration spec.)

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Statistical Computers Can *Really* Reduce Data

THE GIST: The long columns of numbers often produced by conventional data logging systems require laborious effort if the significant process trends are to be picked out. Pinpointing the reasons for abnormal readouts is also slowed by the mass of data, and even random errors printed out as abnormal readings cause worry, when actually they can be safely ignored.

Author Schubert shows by example that statistical data reduction computers can alleviate these problems. Data can be presented succinctly and with proper significance. Direct indications of drifting mean values, standard deviations, and trouble spots simplify the operator's job of adjusting for improved control. And if process time constants are too short for safe human supervision, statistical computers can be included directly in the automatic control system.

E. J. SCHUBERT, Monitor Systems, Inc.

The "flow" of parts on an assembly line or of production pieces in an automatic machine tool can be compared to the continuous chemical process. Significant parameters of the products are variable and must be controlled. For example, variations in the concentration of a chemical product might have the same significance to the chemical engineer that fluctuations in the diameters of steel balls would to a mechanical engineer. Since mechanical manufacturing and assembly processes turn out discrete items, statistical techniques based on manual measurements have been used for some years to reduce and even eliminate rejects and the expense of matching machined parts that must mate. More recently the statistical technique has itself been automated to control the percentage of rejects on some automatic machinery.

These same statistical quality control concepts are usually also valid for control of continuous chemical processes. Multiple-point scanning systems such as are used with data loggers produce the discrete form of data needed for input to a statistical com-

TABLE I—
Conventional

Typical logging record in conventional format used in petroleum industry plots values of all points at regular time intervals. Off-value points are generally printed in red.

DATA LOGGING

CODE = ON L. SIDE	TIME	DEHYDRATING COLUMN											RECOVERY COLUMN										CONCENTRAT								
		FLOW				TEMP							FLOW				TEMP						FLOW								
		FEED	STM. TO REBOIL	ACETONE HEADS	REFLUX	FEED	BOTTOMS	6TH PLATE	TOP PLATE	REFLUX	ACETONE HEADS	DEHYD. COL. PRESS.	FEED	STM TO COLUMN	REFLUX	DWG RECYCLE TO DEHYD COL	BOTTOMS	15TH PLATE	TOP PLATE	REFLUX	DWG RECYCLE TO DEHYD COL	REC COL PRESSURE	FEED	REFLUX	STM TO REBOIL	SIDE PRODUCT	BOTTOMS	15TH PLATE	TOP PLATE	BOTTOMS
		FRC 301	FRC 302	FRC 303	FR 301	TP 325	TP 313	TP 319	TP 302	TP 330	TP 303	PRC 301	FRC 304	FRC 305	FRC 309	FR 309	TP 312	TP 311	TP 310	TP 339	TP 342	PR 301	FR 302	FRC 307	FR 304	FR 305	FR 306	TP 340	TP 304	TP 309	T
		GPH X10	GAL/HR X10	GPH X.1	GPH X10	°F X1	°F X1	°F X1	°F X1	°F X1	°F X1	PSIG X.1	GPH X0	GAL/HR X10	GPH X1	GPH X1	°F X1	°F X1	°F X1	°F X1	°F X1	% LC X.1	GPH X10	GPH X10	GAL/HR X200	GPH X10	GPH X1	°F X1	°F X1	°F X1	
	TIME	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	
	0300A	619	597	779	735	226	309	304	258	192	064	747	741	744	728	767	058	054	052	052	052	745	732	761	786	735	735	226	187	234	
E	0330A	455	440	557	538	226	309	305	258	192	064	748	550	552	537	567	059	054	053	052	053	744	556	573	568	551	552	223	186	236	
	0400A	661	647	824	799	227	307	303	257	191	064	742	772	784	867	798	059	054	054	054	055	745	772	787	791	866	777	223	187	234	
	0430A	629	615	781	752	226	307	304	257	190	064	740	750	752	740	771	057	055	053	051	052	740	740	760	768	740	752	223	187	234	
	0500A	638	616	806	782	227	306	307	259	192	064	751	782	794	878	802	060	057	054	054	054	744	765	786	783	858	772	223	187	235	
	0530A	628	615	784	757	226	312	305	257	190	065	742	759	762	747	777	059	056	054	053	053	743	745	772	778	755	767	224	188	236	
	0600A	658	664	796	758	222	302	303	257	190	064	741	764	777	852	792	059	055	056	051	052	742	762	783	779	845	767	223	187	236	
	0630A	638	621	785	758	223	308	305	257	190	063	742	760	768	755	779	059	055	056	053	053	744	752	778	787	759	762	223	188	235	

puter. But the data logging systems themselves generally present a tremendous amount of data which requires further analysis that is very costly and may prevent fast corrective action (see Table I). A statistical computer in the logging system can present more meaningful data directly.

Statistical quality control techniques generally assume a Gaussian distribution of measurements. The example mentioned above for measuring the diameter of steel balls manufactured for ball bearings is typical. After being sorted for size, balls of any given nominal diameter will still individually vary from this nominal within some acceptable range. The Gaussian distribution of these diameters can be shown by dividing the diameter range into small increments and plotting the number of balls in each increment against diameter, as in Figure 1A. Increasing the total number of balls measured and reducing the diameter increments will cause the staircase curve of Figure 1A to approach the familiar bell-shaped Gaussian curve of Figure 1B.

A Gaussian distribution curve can be completely defined by two dimensions: its mean value and its standard deviation. The mean value x is the arithmetic mean of n values of a parameter x. That is:

$$\bar{x} = \frac{1}{n}\sum_{j=1}^{n} x_j \qquad (1)$$

The standard deviation σ defines the width of the distribution curve and is used to determine the percentage of acceptable items in a sample lot.

$$\sigma^2 = \frac{1}{n}\left(\sum_{j=1}^{n} x_j^2\right) - \bar{x}^2 \qquad (2)$$

As an example, for a Gaussian distribution, 99.7 percent of all items will lie within plus or minus 3σ

HOW STATISTICAL DISTRIBUTIONS ARE DEVELOPED

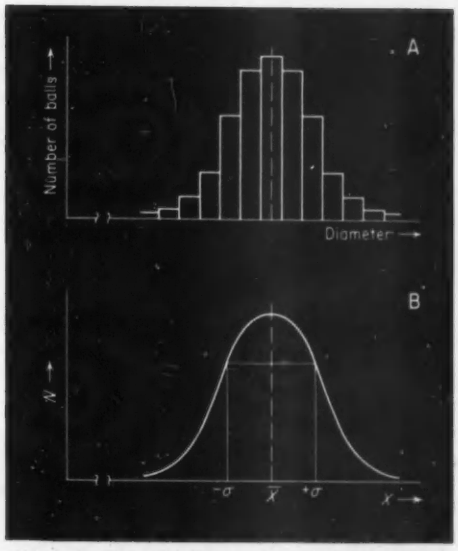

FIG. 1. A—For steel balls of same nominal diameter, plot of number of balls in small diameter increments vs diameter will have distribution as shown. B—Increasing total number of balls and decreasing measurement increment will cause plot in (A) to approach Gaussian curve with mean value x and standard deviation plus or minus σ.

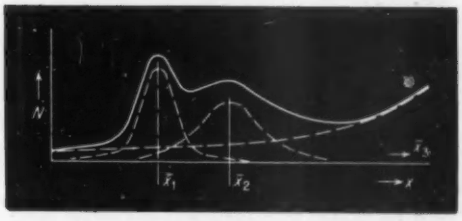

FIG. 2. Complex distributions can often be resolved into superposition of simple Gaussian curves.

MAY 17, 1959			OPER SPEX 51/10-7-58		
0517	A5	4	HV	730.81	HI 000.21
0622	A5	7	3SD	010.73	HI 000.73
0632	A5	7	3SD	010.98	HI 000.98
0642	A5	7	3SD	011.04	HI 001.04
0643	A5	7	NS		ALARM ON
0659	A5	7	OK		ALARM OFF
0709	A5	7	3SD	010.69	HI 000.69
2206	B3	1	HV	826.71	HI 001.71

TABLE II—Statistical

Statistical data logging record of abnormal points only. Columns, left to right, tell operator: time of fault or change, area of process involved, test point number, setpoint value or reason for alarm, amount of error or alarm status.

SNO 310476	MOD 76D	SPEX 178/12-3-58	
07	3SD 25.6	? THERMOSTAT	
17 HV 14.5	3SD 8.3	? FAN BELT	
SNO 310477	MOD 76D	SPEX 178/12-3-58	
		OK	
SNO 310478	MOD 76B	SPEX 152/9-17-58	
28 HV 35.2		? COMPR ZYL 5	

TABLE III—Statistical

Statistical data logging record for automatic engine testing. First line for each engine shows engine serial number, model number, and applicable specification. Following lines show only tests that fail to meet specification limits.

of the mean value of the parameter measured.

Since most parameter distributions are Gaussian, it is possible to detect the influence of various factors in a complex distribution, see Figure 2.

Statistical measurements for controlling production of the steel balls can be made automatically by the analog computer shown in Figure 3. A conveyor carries the balls in the direction of the arrow past two transducers. After the first ball has passed both transducers, integrator I will always contain the sum of the latest n diameter readings. Its output is therefore the mean value of the readings (times the fixed scale factor n). Similarly, integrator 2 sums the squares of the latest n diameter readings,

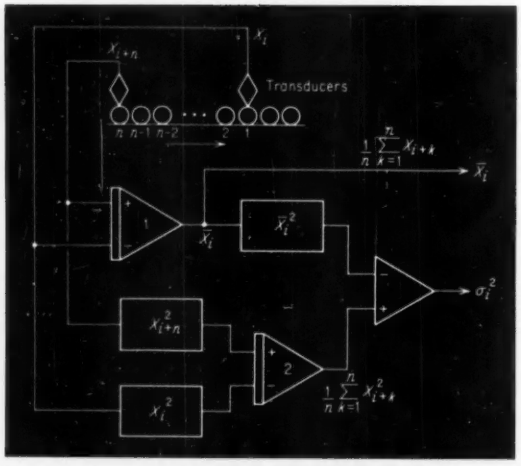

FIG. 3. Analog computer for continuous calculation of mean values and standard deviations applied to steel ball problem.

and subtracting the square of the mean value produces the square of the mean deviation. This computing scheme becomes economically impractical if more than a very few individual parameters must be evaluated statistically. But the inputs to the computer could just as well be temperature measurements as diameter readings.

A statistical plot of 106 temperature readings taken sequentially on a single process test point is shown in Figure 4. The information is much more intelligible in this form than it would be as an analog recording on a strip chart or logged as in Table I.

Present methods of logging data for later reduction emphasize the mean value and detection of extremes during the observation. Unfortunately, such extremes are random data without any statement of their probability and may have little or no meaning with respect to the stability of the measured parameter. In the light of the statistical presentation of Figure 4, the true significance of recorded extremes can be appreciated. For example, a high

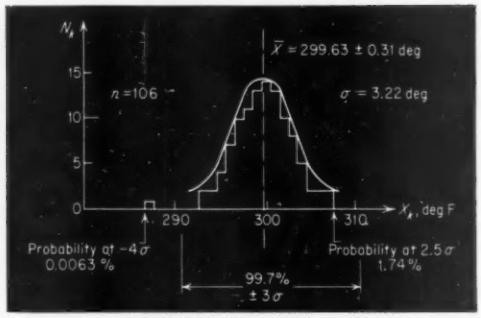

FIG. 4. Gaussian distribution of temperature measurements made sequentially at same test point.

reading at 2.5σ would have a probability of 1.74 percent; but a reading at minus 4σ has a probability of 6.3×10^{-5}, which is very unlikely and might be considered as a measurement error.

Table II is a log sheet for a continuous process monitored with a statistical data-reduction system. All mean values and standard deviations are compared with reference values stored in a digital computer system. The log sheet produced by the printer compiles abnormal conditions only. Closed-loop control is not necessary if it is known that the time constants of the system are long enough to permit corrective action by human operators. In the column at the right, the messages to the operator are specifically indicated. The source of trouble is properly identified and the unpermissible deviation is quantitatively given to aid the operator in his control function. This concise report is also acceptable to management personnal and may be retained as a permanent record of process performance.

The first column is obtained from a digital clock. In the second column the code indicates the area of the process in which the malfunction occurred. The third column designates the local test point. Following entries give specifically the mean value (MV) or three times the standard deviation (3 SD) in numerical form. The unpermissible excursion is listed in the last column.

The first line records a small drift in the mean value measured at 5:17 A.M. in area A5, test point 4. In the same area some trouble occurred in the control loop of test point 7, indicated by an excursion of the standard deviation +0.73 in excess of the specified range. At 6:43 A.M. the data reduction system generated an alarm indicating the No Signal was being received from test point 7. Restored normal conditions were confirmed at 6:59 A.M. The repair was successfully completed after 7:09 A.M. At 22.06 (10:06 P.M.) a drift in the mean value at station B3, test point 1 was observed.

Table III is another example of statistical data logging for complex equipment, in this case an automatic engine test station. The statistical computer contained the specifications, including appropriate

tolerances, in its memory. Depending on the model number, which is entered into the computer together with the serial number (SNO) at the beginning of the test, the data are compared with specified limits. An interpretive routine codes the test as indicated in the first column and prints an appropriate message on the report. Indication of successful completion of the whole test sequence is restricted to the entrance of an OK message.

The basic philosophy in the data reduction system for such an application is to improve communication between the computer and human operators by restricting the information to relevant facts. If quality control data for the whole batch of produced items are desirable, then an auxiliary printer for continuous monitoring could be connected temporarily. In lieu of monitoring, however, a secondary statistical routine should compile mean values and standard deviations for the whole batch.

Statistical data reduction for complex systems

Figure 5 shows a digital system capable of statistical data reduction in real time. The analog input information is sampled with a suitable scanning mechanism. Appropriate scaling and offset can be introduced in analog form. The conversion from analog to digital notation can be obtained in linear and square analog to digital converters. A fast binary adder accumulates the individual readings in two registers reserved for each sample point. Automatic rescaling of register content is provided to eliminate overflow. Interlaced with or following the accumulation of data, the content of the individual registers is fed into a slow arithmetic unit with a conventional stored program. The slow decimal subsystem processes the statistical data into final form, using punched paper tape for format control and insertion of fixed information. A conventional electric typewriter presents the condensed results.

It is somewhat difficult to classify this data reduction system with respect to conventional computer techniques. It actually is three subsystems:

1. The slow decimal subsystem is a conventional stored-program general purpose computer. It operates on the statistical data stored in one section of the drum. Program storage and circulating loops for operational registers are provided in another section.
2. The fast binary subsystem resembles a digital differential analyzer. The major difference from conventional DDA's is a fast binary full adder which allows adding numbers without restriction to specified increments.
3. The third subsystem converts the analog input signals to digital information by means of feedback loops containing digital attenuators. The squaring converter places an additional digital attenuator in cascade with the analog input to form a multiplier.

Capabilities of the computer

A digital computer for the system of Figure 5 is presently in the equipment design stage and comprises 4,800 registers in the high speed section, each for a 20-bit word. The hardware for fast binary addition is modest due to serial operation. Interlaced with the continuous scanning operation is a read-out period for any selected register into the slow decimal subsystem. The program memory can contain up to 1,000 instructions. One track is reserved for operational purposes using a series of circulating loops. A stored routine converts the final results from binary into decimal notation. For full flexibility in data reduction, a translator into any desired code is provided using a section in the memory.

The use of the slow decimal computer with a serial translation is consistent with the basic philosophy of real time data reduction when the output is restricted to significant information only. Then

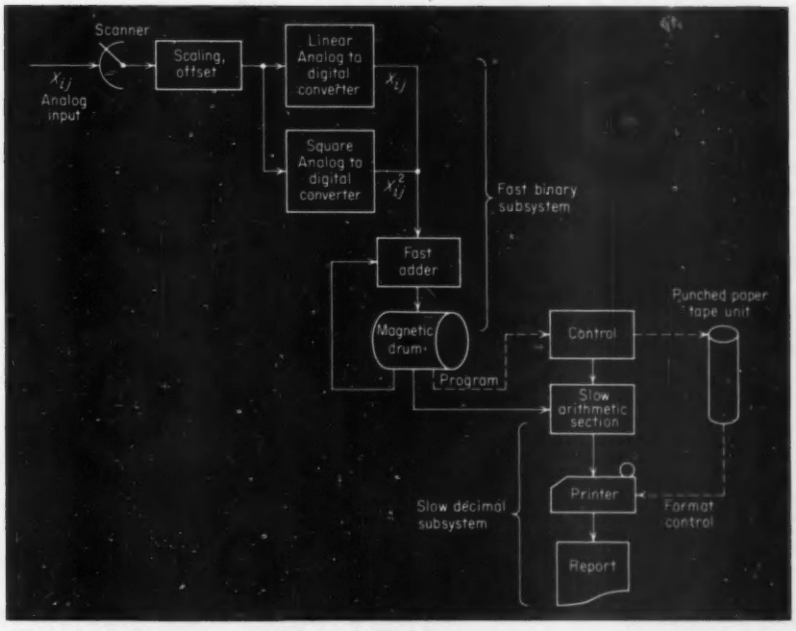

FIG. 5. A digital computer practical for statistical data logging of many variables in complex systems.

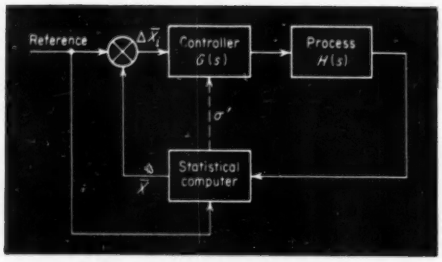

FIG. 6. Statistical control system suitable for use with analog computer of Figure 3.

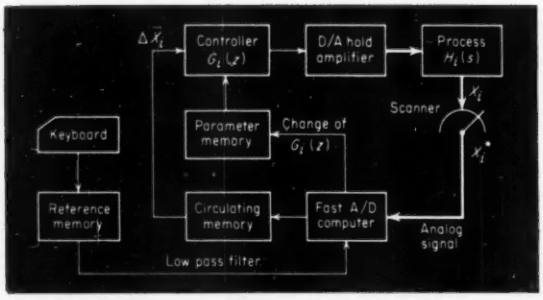

FIG. 7. Hybrid analog/digital system for statistical control of complex systems.

the communication between system and operator requires a very modest amount of printed data.

The fast binary subsystem can be used to analyze complex distribution curves with respect to superpositions such as the one shown in Figure 2. Such an analysis discloses the effect of several factors on the distribution of measurements. Each of the registers can be operated as counter N_k for the readings X_k. The differentiation dN/dX detects the maximums and therefore isolates the individual Gaussian distributions, providing the assumed superposition principle applies.

In many data reduction and control problems, integration and differentiation by finite differences are required. One particular application is the detection of high frequency components (i.e., fast changes in a parameter) by continuous computation of the differences between successive samples. With existing hardware more than 10,000 linear and square analog to digital conversions per second can be made with an accuracy of 0.05 percent. These advantages and highly efficient digital storage that is available justify the contemplated systems concept of a hybrid machine.

Control loops containing statistical computers

The temperature readings represented by the distribution in Figure 4 are typical for the performance of a thermostatically controlled oven. If a control accuracy of plus or minus 10 deg is sufficient, then the performance characterized by the range of plus or minus 3σ is satisfactory. A change in the reference setting would force the feedback system to follow the generated error signal ΔX_i which is the difference between the mean value $\overline{X}$ and the reference input, see Figure 6. Computing the deviation σ with respect to the reference setting yields an excessively high value σ' during the time that the reference is changing.

Without going into the deviation of the control response, it can be stated that the optimum transfer function $G(s)$ for the controller can be affected by σ'. Superficially, very small values of σ' permit reducing the gain of the controller. Large values of σ' indicate insufficient gain in the controller.

Figure 6 is a rather basic feedback loop which can be mechanized by the analog technique in Figure 3. To operate on a large system by multiplexing digital techniques, however, requires some auxiliary loops. Figure 7 illustrates a sampled control system with a reference memory for either stationary or dynamic inputs into the system. The digital controller specifies a transfer function $G_i(z)$ for each signal X_i by corresponding parameters stored in a section of the memory. The control signal, appropriately processed, is retained in a hold amplifier after digital-analog conversion. This hold amplifier can be mechanized as the setting of a valve, positioning of a tool or gate, etc. Its effect is a staircase input into the process referred to the individual transfer function $H_i(s)$.

The width of the steps in this staircase corresponds to one sampling period. Samples of the signals X_i are obtained at the output of the scanner and fed into a fast analog-digital computer. This section performs analog-digital processing, conversion, and digital storage. Appropriate changes for the parameters of the transfer functions are computed and transferred into the parameter memory. The updated mean values $\overline{X}_i$ are maintained in a circulating memory according to Equation 3, virtually eliminating the comparator as such. As a matter of expediency, the deviation is computed as follows:

$$\Delta\overline{X}_i = \frac{1}{n}\sum_{j=1}^{n}(X_{ij} - Y_i) \qquad (3)$$

$$S_i = \frac{1}{n}\sum_{j=1}^{n}(X_{ij} - Y_i)^2 \qquad (4)$$

$$\sigma_i^2 = S_i - (\Delta\overline{X}_i)^2 \qquad (5)$$

in which Y_i is the reference setting for parameter i. The standard error m of the mean value is

$$m = \sigma/\sqrt{n} \qquad (6)$$

and indicates how little improvement can be expected by increasing the number n of readings X_i.

Transistor-Relay Hybrids

. . . for close-differential switching

A unique transistorized trigger circuit provides a real breakthrough in the construction of close-differential relays. By using the circuit in series with the control coil of a conventional electromagnetic relay, it is possible to shrink the difference between pull-in and drop-out voltages to only 1 percent.

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Maico Electronics, Inc.

A common requirement in the design of automatic control systems is the operation of the load contacts of dc electromagnetic relays with a minimum change in control coil voltage. This is known as close-differential switching. Unfortunately it is ordinarily not easy to meet this requirement because the relay is inherently a wide-differential component. Run-of-the-mill relays, for example, have a two to one ratio of pull-in to drop-out voltage. The load contacts of such a relay would close when the voltage across the control coil was raised to, say, 20 volts. However, because fewer ampere-turns are needed to *hold* a relay than to *operate* it, the contacts will not open again until the control signal drops to 10 volts. In terms of a percentage of pull-in voltage, this relay may be described as having a differential of 50 percent.

On special orders, relay manufacturers can supply almost any type of unit adjusted for operation at differentials of 25 or 30 percent. But 10 percent differential relays are rare, and the control engineer looking for anything better than this is fated for a fruitless search. Fortunately it is possible to enhance a relay's characteristics considerably by combining it with various types of preamplifiers or triggers to form hybrid close-differential units. One hybrid that produces startling results for close-differential switching employs a transistorized version of the Schmitt trigger circuit. A design description and evidence indicating the practicality of the circuit from the standpoints of interchangeability and temperature stability should be of benefit to design

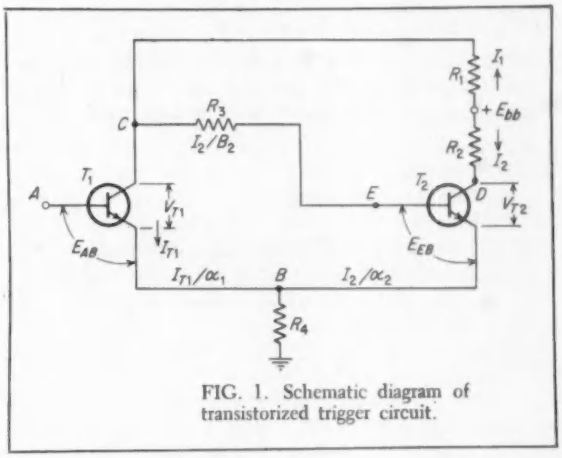


FIG. 1. Schematic diagram of transistorized trigger circuit.

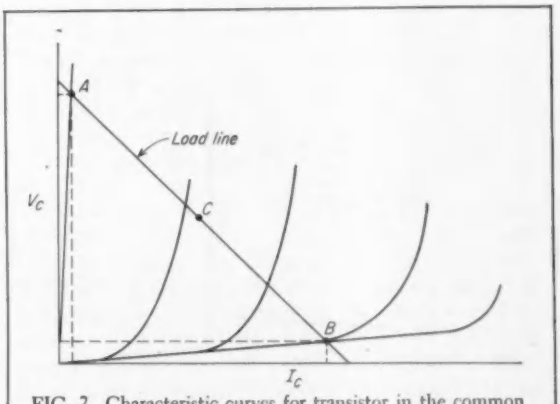


FIG. 2. Characteristic curves for transistor in the common emitter connection with load line superimposed.

engineers facing switching problems of this type.

Design considerations

The transistorized trigger circuit is shown in Figure 1. In this application the transistor is used in the switching mode, which means that at any given time it is either completely nonconducting or fully conducting (saturated). The transistor operates most efficiently under these conditions as can be seen from the characteristic curves of Figure 2. The transistor switch is either in condition A or condition B, and it is apparent that at both points dissipation is relatively small. Maximum dissipation occurs at point C, but the transition from A to B or B to A is sufficiently rapid so that the average transistor dissipation is extremely low.

With reference to Figure 1, T_2 is initially fully on and T_1 fully off. The base current of T_2 flows through R_1 and then through R_3, which can be adjusted to establish sufficient voltage at E for the fully-on condition of T_2. The emitter current of T_2 produces a voltage drop across R_4. The resulting potential at B keeps T_1 completely off until the signal at A becomes sufficiently positive with respect to B to initiate conduction in T_1. Now the T_1 collector current starts to flow through R_1 and increases the voltage drop across this resistor. Point C, therefore, becomes less positive with respect to B, tending to reduce conduction in T_2. As the current of T_2 lessens, the potential at B with respect to A drops and thus accelerates conduction in T_1. This in turn speeds the decrease in potential at C and the cutoff of T_2, until finally T_2 is cut off and T_1 becomes fully conducting. This condition is maintained as long as the potential at A is sufficiently greater than the voltage at B.

When the signal at A becomes less positive with respect to B, the T_1 collector current is reduced, tending to increase the potential of C with respect to B and the potential of E with respect to B. Conduction in T_2 begins, and the resulting emitter current increases the voltage drop in R_4. The higher potential at B hastens cutoff of T_1 which in turn causes an increase in potential at C and accelerates the firing of T_2. By replacing R_1 or R_2 or both with relay control windings, the switching action described can be used to activate the relays as desired.

A simple analysis of Figure 1 produces relationships from which approximate component values can be established for the purpose of constructing experimental models. From Figure 1 the following equations are evident:

$$I_1 = I_{T_1} + I_2/\beta_2 \tag{1}$$

$$E_B = R_4\left[\frac{I_{T_1}}{\alpha_1} + \frac{I_2}{\alpha_2}\right] \tag{2}$$

$$E_{bb} = R_1 I_1 + \frac{R_3 I_2}{\beta_2} + E_{EB} + R_4\left[\frac{I^{T_1}}{\alpha_1} + \frac{I_2}{\alpha_2}\right] \tag{3}$$

$$E_{bb} = R_1 I_1 + V_{T_1} + R_4\left[\frac{I_{T_1}}{\alpha_1} + \frac{I_2}{\alpha_2}\right] \tag{4}$$

$$E_{bb} = R_2 I_2 + V_{T_2} + R_4\left[\frac{I_{T_1}}{\alpha_1} + \frac{I_2}{\alpha_2}\right] \tag{5}$$

For T_2 normally on and T_1 normally off:

$$I_{T_1} = 0$$

Therefore, from Equation 1:

$$I_1 = I_2/\beta_2 \tag{6}$$

Then Equation 5 becomes:

$$E_{bb} = R_2 I_2 + I_2 R_{SAT2} + \frac{R_4 I_2}{\alpha_2} \tag{7}$$

where R_{SAT2} is the maximum saturation resistance as specified for the transistor. Solving Equation 7 for R_4:

$$R_4 = \frac{\alpha_2(E_{bb} - R_2 I_2 - I_2 R_{SAT2})}{I_2} \tag{8}$$

and from Equation 3:

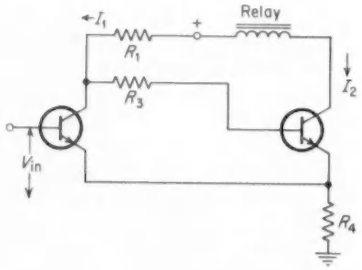
$$R_1 + R_3 = \frac{\beta_2}{I_2}(E_{bb} - E_{EB}) - \frac{\beta_2 R_4}{\alpha_2} \tag{9}$$

To switch T_1 on and T_2 off, the input voltage required at A is:

$$E_{SW/ON} \geqq E_{AB} + E_B = E_{AB} + \frac{I_2 R_4}{\alpha_2} \tag{10}$$

For T_1 normally on and T_2 normally off:

$$I_2 \cong 0$$



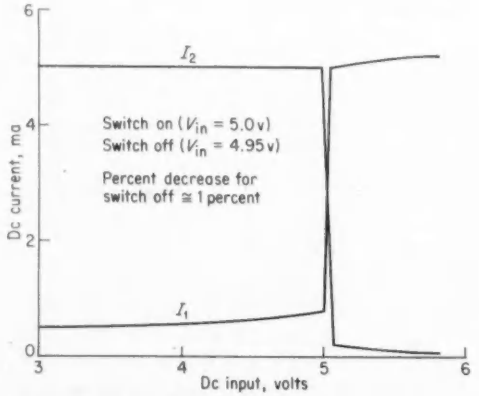


FIG. 3. Switching response for transistorized triggering circuit connected as shown.

Therefore, $I_1 = I_{T_1}$ (11)

Equation 4 becomes:

$$E_{bb} = R_1 I_{T_1} + \frac{R_4 I_{T_1}}{\alpha_1} + I_{T_1} R_{SAT1} \quad (12)$$

Now, solving Equation 12 for R_1:

$$R_1 = \frac{E_{bb}}{I_{T_1}} - R_{SAT1} - \frac{R_4}{\alpha_1} \quad (13)$$

Substituting Equation 13 in Equation 9 and solving for R_3:

$$R_3 = \frac{\beta_2}{I_2}(E_{bb} - E_{EB}) - \frac{\beta_2 R_4}{\alpha_2} - \frac{(E_{bb} - I_{T_1} R_{SAT1})}{I_{T_1}} - \frac{R_4}{\alpha_1} \quad (14)$$

For effective switching interaction, R_3 should be greater than R_1 by a factor of 10. To switch T_1 off and T_2 on, the voltage at A must reach:

$$E_{SW/OFF} \leqq E_{AB} + \frac{I_1 R_4}{\alpha_1} \quad (15)$$

From the preceding relationships and knowing E_{bb}, α_1, α_2, R_{SAT1}, and R_{SAT2}, the dc resistance of the relays and the relay energizing current, the approximate component values, and switch-off and switch-on voltages can be determined for the switching circuit. In the event a particular $E_{SW/ON}$ or $E_{SW/OFF}$ is required, the value of R_4 that should produce the desired voltage can be found from Equations 10 and 11, respectively. The base-emitter voltages, E_{AB} and E_{EB}, are approximately equal; typically for germanium they are about 0.1 volt and for silicon about 0.6 volt. Due to the dependence of the value of R_3 on the alpha of T_2, it may be necessary in an experimental model to vary R_3 from the calculated value in order to achieve saturation of T_2 for the selected load resistance.

Experimental circuit performance

A laboratory model of the preceding circuit was constructed and its effectiveness in energizing a relay was noted. As indicated in Figure 3, it was found that switch-on and switch-off voltages could be controlled to within 1 per cent. Rise and fall times were about 4.0 microsec. To observe the fidelity of the switch-on voltage with various transistors, ten pairs of 50-milliwatt NPN transistors representing a wide range of characteristics were interchanged in the switch with no other change being made in circuit components. The switch-on voltage was found to hold constant with a deviation of no more than 3 percent of a nominal value.

The experimental breadboard was then exposed to a temperature range of −55 deg C to 100 deg C. At the temperature extremes, the switch-on and switch-off voltages held constant to within 3 percent of the 25 deg C value.

Further evidence of the stability of this relay driving circuit is demonstrated by the graphs of Figure 4. These curves demonstrate the consistency of switch-on and switch-off voltage values for a wide range of

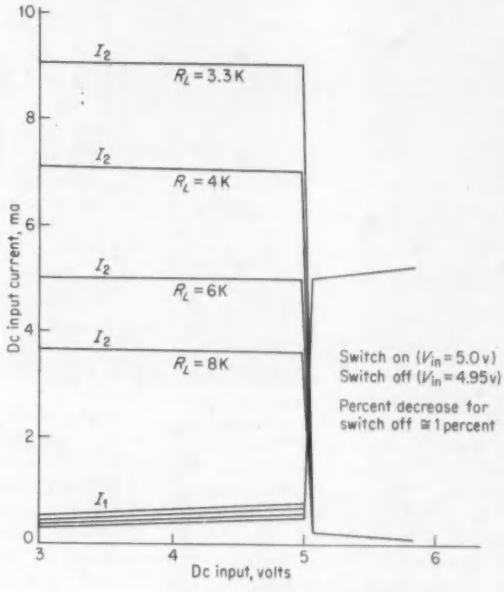


FIG. 4. Switching response as a function of load resistance

dc load resistances. It is noted that the percent decrease for switch-off remained about the same, less than 1 percent for the various load resistance values. Since the resistance values could represent the dc winding resistance of a current activated relay, it is evident that a wide selection of relays could be accommodated without need for changing the given driving circuit.

Using the current and resistance values from the experimental circuit, it is seen that dc relays having energizing power requirements ranging from about 110 to 270 milliwatts could be handled. This approximately 3 to 1 power range ratio could quite conceivably be extended through component selection and further circuit optimization. It is understood that the experimental results being discussed are characteristic of the triggering circuit using one type of transistor and with component values determined for arbitrarily selected switch-on voltage. The capabilities of the circuit may be further extended through use of other types of transistors and with circuitry values based on some other switch-on voltage.

Examination of Figures 3 and 4 brings out further versatility in this circuit. It is seen that both I_1 and I_2 characteristics can be used for relay operation. Thus, the triggering circuit has the capability of handling two relay activating functions simultaneously by replacing R_1 of Figure 3 with a second relay winding. As one example of usage, if both relays were "normally open when energized" types, upon applying switch-on voltage, one relay could open one circuit while the second closed another.

Transistorized Length Gage Scans Hot Steel

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E. R. SAMPSON
General Electric Co.

A transistorized scanning system has been satisfactorily measuring the lengths of moving hot steel slabs as they leave Lukens Steel Co.'s new computer-operated hot plate mill at Coatesville, Pa. (see CtE, January '60, pp. 126-130). The length gage diagrammed in Figure 1, mounts a rotating optical system containing infrared sensitive phototransistors 55 ft above the run-out tables on one end of the reversing mill. Accuracy of the gage meets specifications, which require plus or minus ½ in. maximum length error for slabs 30 to 140 in. long in a thickness range from 3 to 8 in. and plus or minus 1 in. maximum error over the whole range of lengths (30 to 204 in.) and thicknesses (1¼ to 30 in.). Steel temperature can vary from 1,600 to 2,200 deg F, and slab speed can range up to 500 ft per min.

Hot steel enters a 17-ft long measuring zone as it emerges from the mill on the operator's side and is scanned 120 times per sec by the eight-lensed drum shown in Figure 2. The 2N469 phototransistor that looks at the steel through these lenses generates an electrical pulse, the "see-steel" signal, which is proportional to the length of the slab. The scanning transistor is mounted at the center of the drum, and a cylindrical lens placed in front of the drum increases the viewed area of the slab to a 20-in. wide strip only ½ in. long. The limited length resolution caused by the ½-in. viewed length is improved by averaging eight scans.

The length of the measuring zone on the run-out table is determined by the optical system. A small hole drilled in the side face of the drum near each of the drum lenses passes light successively to three auxiliary phototransistors to generate "in-zone" reference pulses. The logic circuits in Figure 1 will pass the ' see steel" signal only when it is not present for the first reference pulse, is present for the second, and is not present for the third; that is, only when the see-steel signal is bracketed by the "in-zone" pulses.

Since the length of the see-steel pulse represents the length of the slab to be measured but is also a function of drum speed, the pulse is used to gate a series of high frequency pulses generated by lines engraved on cards fixed to the surface of the drum. Drum speed is essentially constant, so each pulse from the function generator cards represents a fixed increment of slab length, in this case 0.4 in., and the length of the slab is the number of pulses times 0.4 in. Again, the accuracy of the measurement is increased by averaging over eight scans.

Correction of inherent errors

The steel is moving while a measurement is made, so an error occurs. The maximum error due to steel motion will occur at the maximum speed of the steel (500 ft per min or 100 in. per sec) and the longest lengths to be measured (200 in.). The time to scan 200 in. is 0.0032 sec, thus the maximum error due to steel motion is 0.32 in., which is within specifications.

The function generator card from which the unit length pulses are developed is designed to automatically compensate for two other variables inherent in the system: 1) The cosine error due to the fact that the surface of the slab is flat rather than an arc of 55 ft radius; 2) the error due to the effective change in scanning radius and hence included scan angle for different slab thicknesses. The actual arrangement of the engraved lines on the card is shown in Figure 3. The density of the lines increases towards either end of the card in such a way as to vary the pulse frequency to correct for the nonlinear cosine error.

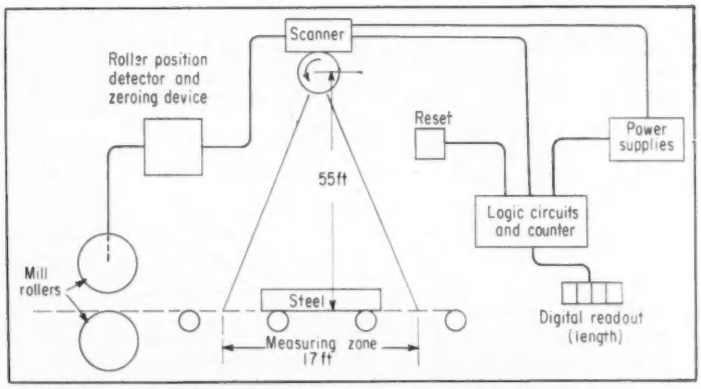

FIG. 1. Scanning length gage uses pulse generated by phototransistor looking at hot steel to gate length-increment pulses generated at drum into counter.

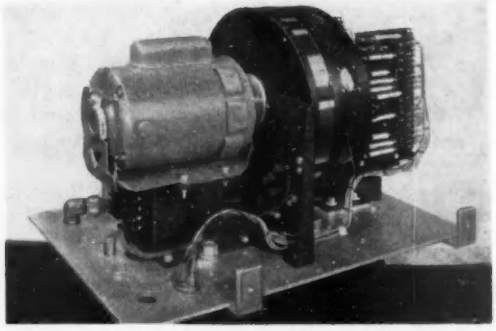

FIG. 2. Scanning drum has eight lenses with phototransistor mounted inside at center, scans steel slab eight times per revolution. Small holes on side face of drum are used with lamps at bottom center to generate zone reference pulses.

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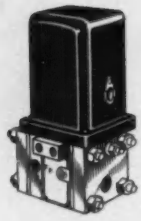

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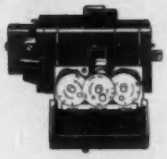

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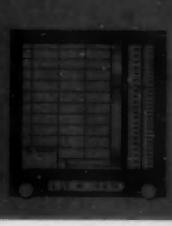

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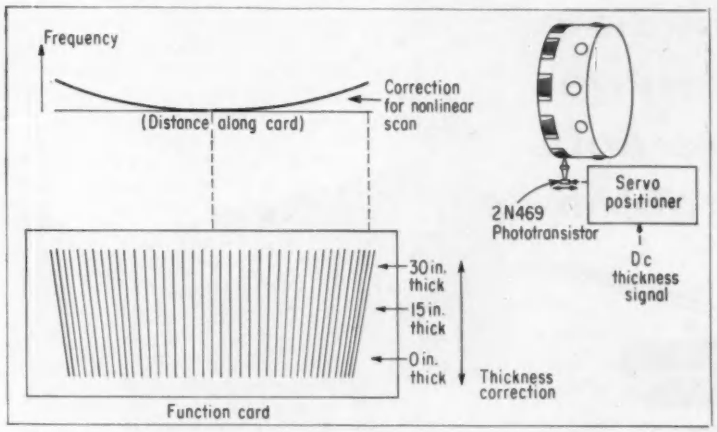

FIG. 3. Function generator card used to generate length-increment pulses corrects for cosine error due to 55-ft radius of scan, and change in scan radius due to thickness of slab.

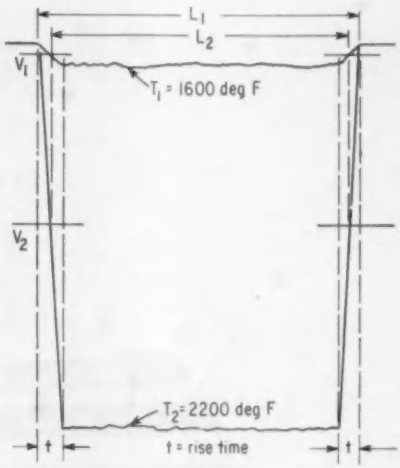

FIG. 4. Temperature range of steel causes 25 to 1 variation in steel signal, and finite rise time can cause serious length error for same slab at two temperature extremes. Error is compensated by sliding gate voltage that causes both temperatures to read length L_s.

Besides this, the lines are arranged in a fan shape across the card. Pulses are generated by light reflected from the engraved lines to a phototransistor that is moved across the card to positions representing different slab thicknesses by a servo that follows the position of the screwdown rolls in the mill. Thus each slab thickness generates a series of pulses of different basic frequency (140 to 160 kc) that varies as the cosine of the scan angle.

One other automatic compensation is necessary to the operation of the length gage. The wide range of temperatures possible during the rolling of a slab of steel causes the amplitude of the see-steel pulse to be 25 times as big at 2,200 deg F as it is at 1,600 deg F. The length of the see-steel pulse must not vary except with changes in the length of the slab. But the pulse has a finite rise time due to optical resolution as well as to electrical circuit response. A gate with a fixed trigger level (low enough to operate on the low-temperature pulse) would indicate different lengths for the same slab at different temperatures. These errors can be as great as 2 in. and must be compensated.

The optical resolution is increased simply by stopping down the effective 50-mil diameter photosensitive zone of the transistor to 5 mils with an aperture mask, and this alone improves the rise time by 10 to 1. The see-steel signal amplifier includes a sliding clamp circuit that allows the signal width to be sampled at different voltages depending on the signal amplitude. For example if the signal is small, it will be sampled at voltage V_1 (Figure 4), and if it is large it will be sampled at V_2.

Oscillograph Reader-Plotters Can Be Breadboarded

D. S. L. DURIE De Havilland Aircraft of Canada Ltd.

During a recent period of flight testing, there was an extra demand for reader-plotter equipment which would replot selected portions of oscillographic records onto graph paper to expedite their interpretation. The extent of the program did not justify the expense of a commercial equipment, so one was built with servo breadboard techniques from standard components on hand in the servo laboratory. Both reader and plotter had to work over 12 x 18-in. areas.

Figure 1 shows the system that was breadboarded. Motor M_1 drives the reader continuously at a convenient speed in the X direction from left to right, while the operator makes the Y carriage follow the oscillographic trace manually. Synchros transmit data from reader to plotter. Follow-up action is provided by Mark 14 motors driving gears meshed with racks. Differential synchros between the transmitters and control transformers provide convenient zero adjustments for the plotter pen.

The X and Y scales of the replotted trace are independently adjustable. The scale in the X direction is ad-

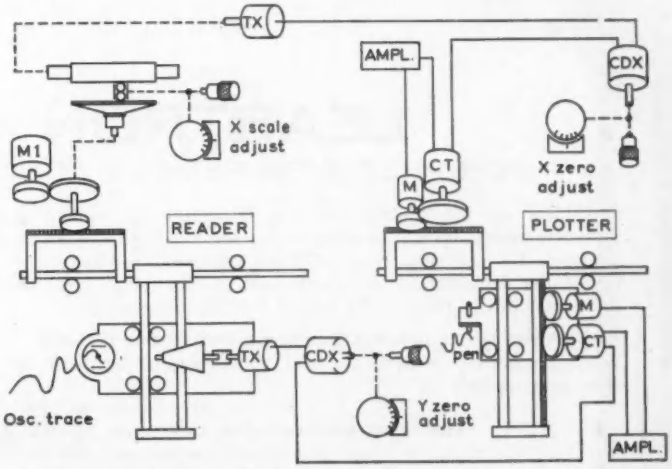

FIG. 1. Reader-plotter system includes adjustable zero and scaling on both axes.

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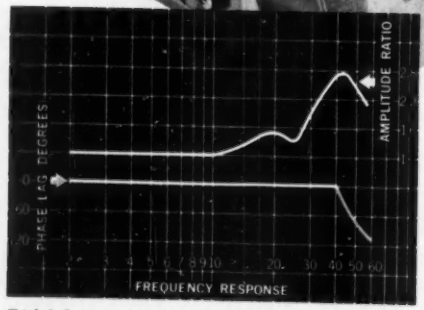
Design Project: ET 580 Component: Remote Servo Positioner
Industrial TV Camera
Design Project: TV 12 Component: Remote Servo Positioner
Function: Traverse Azimuth & Elevation
Specifications: 1. Compactness: Servo 18 lbs. or less; 6" x 14"
Table Positioning Machine Tool Control:
Design Project: AM 412 Component: Remote Servo Positioner
Function: X-Y Table movement.
Specifications: 1. Accuracy: Position lead screw within ¼-degree. (table accuracy .0025 inch)
2. Direction: Forward & reverse.
Remote Positioning—Nuclear Reactor Rods
Design Project: NR 3406 Component: Remote Servo Positioner
Function: Rod position control.
Specifications: 1. Response: Maximum speed within 1/50 second.
2. Accuracy: Within .01-inch over 108" travel.
3. Reliability: Ultimate.
4. Torque: 250 inch pounds @ 12 rpm.
5. Fail Safe: Free fall with automatic braking.
Recommendation: Leartron 60 Approved
Requisition: NR 48261



Total shaft movement equals one-quarter degree.

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justed by varying the position of the ball carriage in a ball-disc integrator. Scale in the Y direction is adjusted by a less orthodox method: the lateral position of a conical odometer wheel. This arrangement is shown in Figure 2. The conical wheel rolls on the rod that guides the Y motion. It and the synchro (11) which picks off its rotation are mounted on a common structure which changes the diameter of the cone in contact with the rod when moved laterally. Rotation of the micrometer screw (14) changes the cone position and therefore adjusts the Y scale of the replotted trace.

In transposing oscillographic traces to graph paper, total errors were to be less than 0.025 in. This figure had to cover errors originating in both operator and machines. The use of antibacklash gears and preloaded bearings held backlash down to a negligible amount. The straightness of the X and Y movements and their orthogonality were carefully controlled. But the precision with which an operator can make a graticule follow a trace depends heavily on human engineering factors. Special attention was given to graticule design, adequate lighting, and optical magnification. Furthermore, the mechanism with which the operator manually controls the graticule was designed to give him adequate mechanical advantage with minimum stiction.

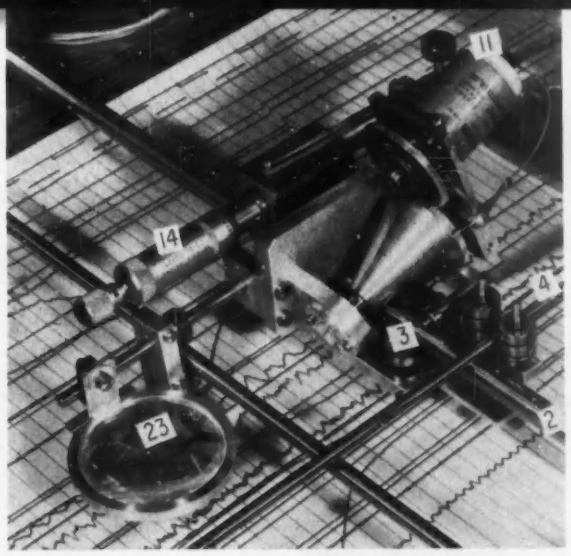


FIG. 2. Y axis scale adjustment is made by conical drive to synchro transmitter.

Russian Train Computer Controlled

G. KONONENKO *"Priborostroenie"* (*"Instrument Construction"*)

A special purpose digital computing-control system has successfully operated an interurban-type electric train on Soviet railways. Designed under the direction of N. Nikolayev, it operates the train without human intervention in accordance with a program that allows for changes in the weather and the condition and profile of the track, and it fixes train speed on individual track sections. The digital computer is designed to perform a numerical integration of the differential equation of motion for the train. This equation accounts for the inertia of rotating parts and the mass of the train, the effective tractive force of the locomotive, the resistance from frictional sources and braking, and the effect of gravity due to track grade. The train velocity and the distance which it has run are set in as initial conditions for each successive solution of the motion equation.

Figure 1 shows the equipment connections in the system. Digital pickups on a locomotive axle transmit velocity v and distance traveled s to the computer, which also gets a time marker t, and an occasional true position marker a from trackside. The operating unit translates computer output commands into signals for controlling the traction motors and brakes and contains alarm units to notify the computer of malfunctions. Information of the profile of the track to be traveled and speed restrictions over the various sections of the route are placed into the computer before a trip in individual casettes via the blocks so marked. Thus the operating conditions are adjusted by the computer to suit a predetermined timetable.

FIG. 1. Equipment connections in digital computer control system that eliminates locomotive engineer.

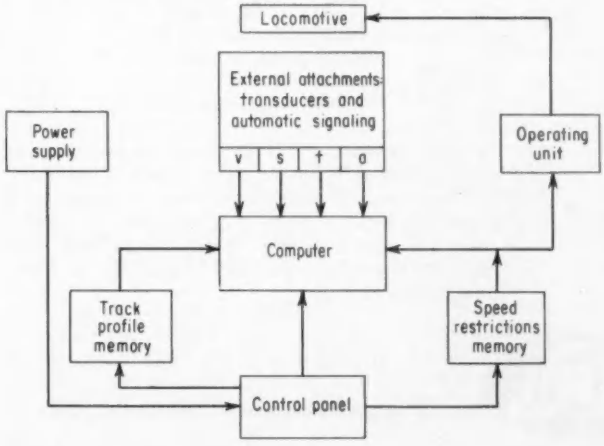
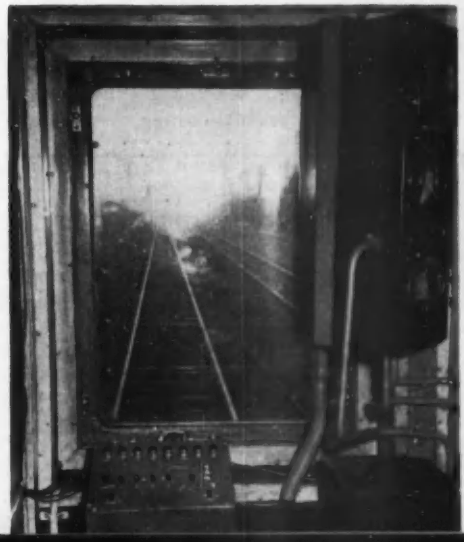


FIG. 2. Simple control panel in driver's cab of experimental train permits manual or automatic mode selection.



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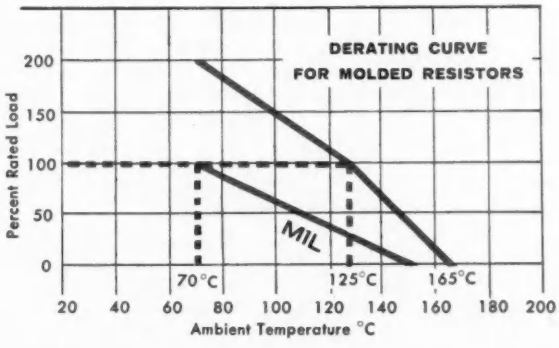
RN60	MDA	.406	.130	10	5M	300	⅛	¼	⅛
RN65	MDB	.594	.203	10	5M	350	¼	½	¼
RN70	MDC	.719	.261	5	25M	500	½	1	½



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Simple Adaptive Controller Combines High Stability, High Accuracy

KARL EKLUND, Wyle-Parameters, Inc.

The Varigain technique described here is perhaps the simplest form of adaptive control, but it makes possible relay-type controls of high accuracy and speed. It operates by input signal adaptation since, as its name indicates, it varies its gain and does so according to the magnitude of the error signal. The Varigain circuit is not, however, merely an amplifier with automatic gain controls, but has three adjustable parameters besides gain that can be used to stabilize a control system.

Figure 1 is the block diagram of the Varigain controller. The output of the power stage is a pair of relay contacts that can power a correcting element, which may be a reversible motor, in which case the relay contacts provide forward and reverse motion depending on the error's sign.

Since this controller has an on-off power element, the gain or sensitivity is described by a deadband, i.e., a region in which the error signal is too small to turn on either relay. When the gain is changed, it reflects itself as a change in deadband width. In the Varigain circuit the gain control stage has two positions, corresponding to a narrow deadband (called the inner or static deadband) for the high gain position, and a wide deadband (the outer or dynamic), corresponding to the low gain position. The ratio of these deadband widths is one parameter varied to provide stabilization.

The position of the gain control depends on the state of the output. When the power stage is activated, a signal is sent to the timer, and after a certain delay, the gain is switched to the low gain position. When the power stage is released, another signal is sent to the timer stage, which, after a second delay, permits the gain control to return to the high gain position. These two time delays are two additional parameters which are varied to obtain system stability.

A Varigain control system is shown in Figure 2. Here the corrector is a doubly lagged integrator, for instance a motor with an overdamped quadratic lag. Figure 3 shows the response of the system to a large initial error. The system corrects for the error until it is within the outer deadband. Since the system is correcting, the gain control is in its low gain position. When the error crosses the dynamic deadband limit, power is removed from the correcting element, which in this case continues to coast, and the timer begins time delay τ_1, after which the gain returns to low gain. Since the error is within the outer deadband, the power stage is again deactivated. This cycle, of power on for time τ_2 and power off for time τ_1, continues until error is within static deadband.

The control action is fairly slow in the region between deadbands, but this slowness is compensated for by the extremely good stability. Figure 3 shows the response of the same sys-

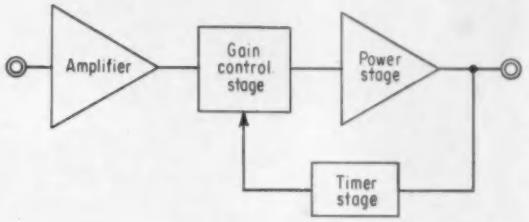


FIG. 1.
Varigain controller has relay output, changes its gain or relay deadband a selected time after the output changes state.

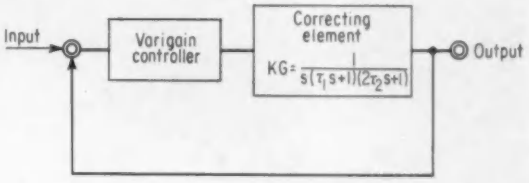


FIG. 2.
Varigain controller in typical closed-loop control system.

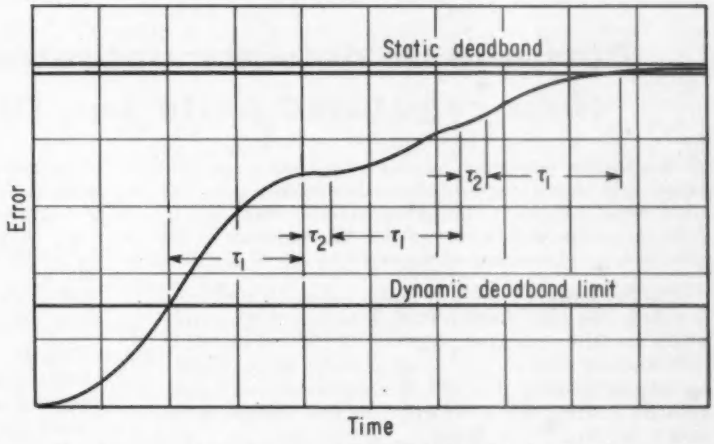
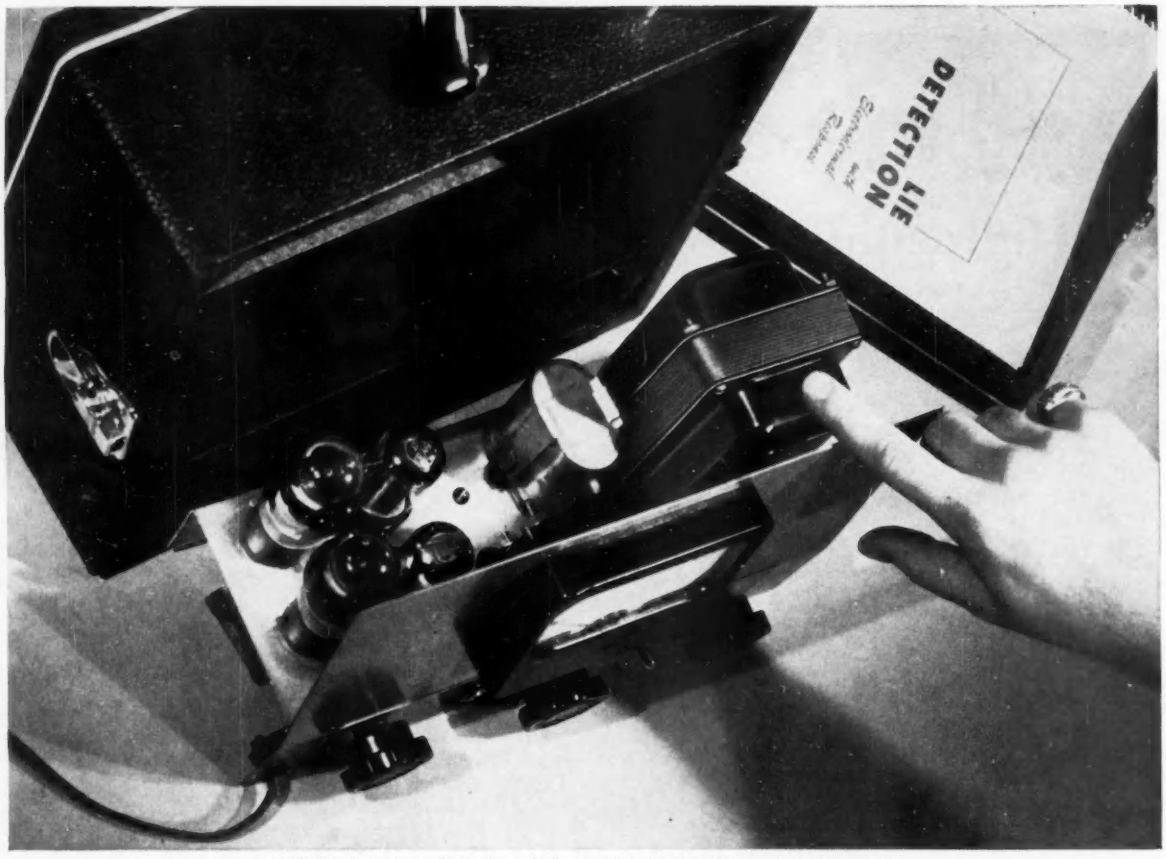


FIG. 3. Response of Varigain system of Figure 2 to large initial error.

CIRCLE 161 ON READER SERVICE CARD



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Besides providing regulation which assures accurate polygraph operation, the Sola transformer protects tubes and components from cold inrush current and from fault currents.

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The plate-filament regulator is only one of the complete family of Sola Constant Voltage Transformers including such special types as filament and adjustable-output units. More than 40 models are available from stock, and Sola manufactures custom-designed units in production quantities to meet special needs.

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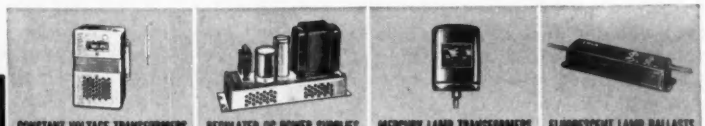

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tem without the Varigain circuitry. To obtain the same degree of stability with this circuit the equivalent static deadband (and therefore the steady state error) would have to be almost as large as the dynamic deadband of the Varigain circuit.

The Varigain circuit acts in effectively two modes. For large errors it acts like a fast operating system which is stabilized by having a wide deadband, while for smaller errors it acts like a high accuracy control, stabilized by having a slow correction speed. These characteristics are normally considered to be mutually exclusive.

The optimum ratio of deadband widths and on-off times depends on the dynamics of the rest of the control system. As a rough rule of thumb the dynamic deadband should be larger than the distance the control will coast after it is shut off, and the on time should be less than the time that would be needed for the error to pass through the static deadband if it had no lags. The off time should be of the same order as corrector time lag.

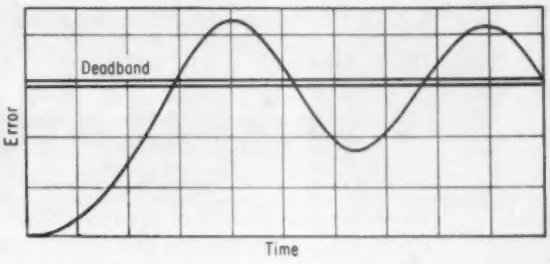

FIG. 4.
Response of system of Figure 2 without Varigain shows poor stability due to tight deadband required for high accuracy.

The Varigain circuit has been packaged as a 3-in. diam by 7-in. long temperature controller weighing less than 2½ lbs, which operates with a fast actuator and slow sensor, to correct large temperature transients (hundreds of degrees) with a static accuracy of a fraction of a degree.

Circuits for High-Ambient, Differential Pressure Measurement

GERALD J. MOYNIHAN
Convair, San Diego

Differential pressure pickups are commercially available for the 5,000-psi ambient range, but very often they cannot be used because the plumbing necessary for their installation would modify the dynamic characteristics of a low volume system. In such cases it has been the practice to record individual pressures while testing and to subtract them graphically later to get differential pressure. This is time consuming and subject to scaling and computing errors. If the calibration on a recording trace is set up for 5,000 psi equals 3 in., and the data reducer can scale to 0.01 in., then the error is 5,000/300 or 16.7 psi. Compared to 5,000 psi this is only 0.33 percent. But if the operating pressure difference is only 100 psi, the error is 16.7 percent and the data may be marginal.

Figure 1 shows one successful solution for recording differential pressure in the presence of high ambient pressure. Two high resolution (0.01 percent) strain gage bridge-type pressure pickups are connected differentially. For a maximum full scale pressure of 5,000 psi, differential pressure resolution of 0.5 psi can be realized. The circuit can be excited with dc as in Figure 1A, in which case summing resistors R_1 and R_2 can be used, or it can be excited with ac by using a carrier modulating-demodulating system and a high impedance summing transformer, as in Figure 1B. In both cases resistor R_f is required to adjust the outputs of the two pickups to equal volts per psi, assuming they are not matched. The ac carrier circuit is generally more desirable because it is less susceptible to 60-cps pickup, and the carrier amplifier can be used to drive a galvanometer directly.

A somewhat better circuit uses the ac carrier technique with resistance summing but requires two carrier amplifiers, Figure 2. This circuit eliminates equalizing resistor R_f because the amplifier gain settings can be used to compensate for the pickup mismatch. It can have lower 60-cps pickup than the circuit of Figure 1B because there is no transformer.

Each of these circuits must be carefully connected to be sure that the pickups are oppositely phased. After the pickup sensitivities have been balanced, ambient pressure change should not change output differential.

The circuit of Figure 2 was used to provide differential pressure feedback to a pneumatic servo in one application, so the relatively high impedance of the output was not loaded by the very high impedance of the servo-amplifier input.

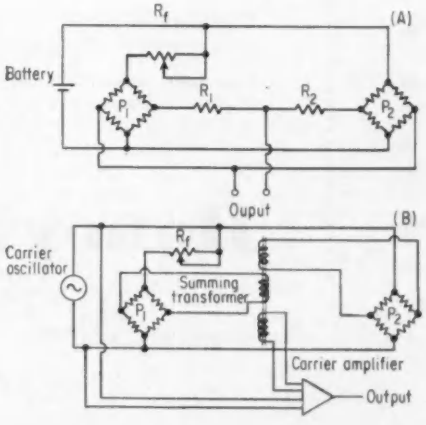

FIG. 1.
A—Circuit for dc excitation of two high pressure, high resolution strain gage bridge-type pressure pickups in differential connection. B—Simple circuit for ac excitation using high impedance summing transformer.

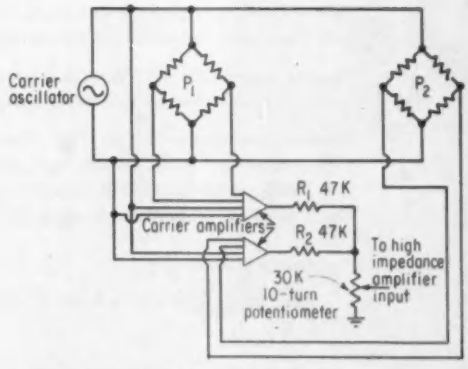

FIG. 2. Circuit for using resistance summing with ac excitation.

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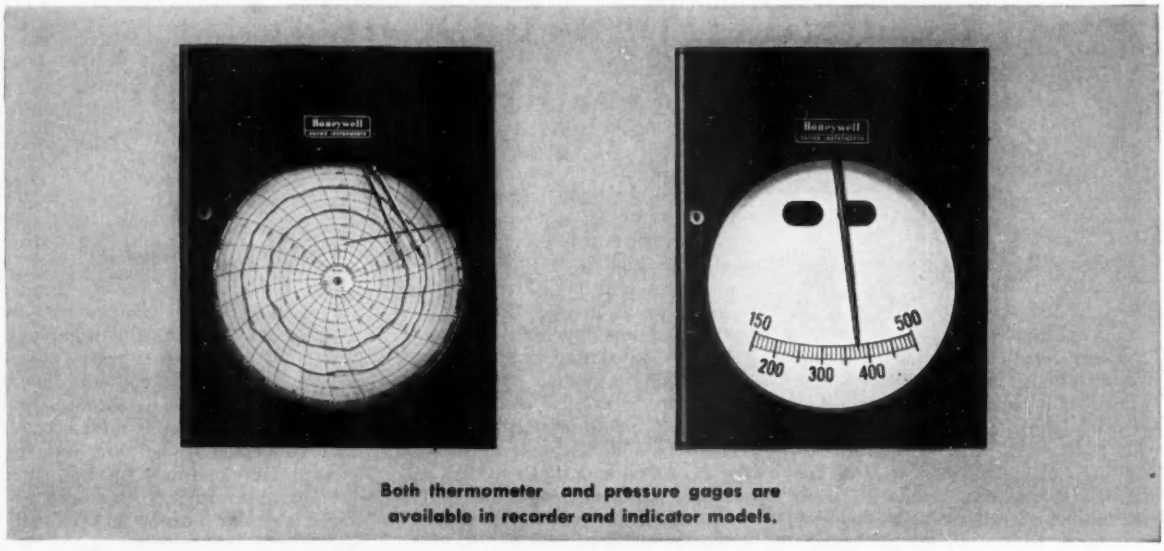
Use Honeywell thermometers to measure temperatures from −125°F to 1000°F, with accuracy of ±1%. Measure pressures as high as 4000 psi and as low as 5 inches of water vacuum with Honeywell pressure gages.

Whatever your requirements in temperature and pressure measurement and control, there's a Honeywell instrument virtually made to order for you. Get complete details from your nearby Honeywell field engineer. Call him today . . . he's as near as your phone.

MINNEAPOLIS-HONEYWELL, Wayne and Windrim Avenues, Philadelphia 44, Pa.



Both thermometer and pressure gages are available in recorder and indicator models.

CONTROL COMBINATIONS AND OPTIONS

TEMPERATURE

Thermal systems—vapor, mercury, or gas actuated, case, case and capillary, or self-compensated.

Bulb styles—plain, union-connected, averaging, preformed capillary, rigid extension, dairy, wet and dry bulb assemblies, self-contained thermal systems.

Electric control—*Electr-O-Vane*, spst (on-off control), spdt (two-position control), sp3t (three-position control).

Pneumatic control—On-Off. 10% *Throttlor* (1 to 10% proportional band, manual reset), *Full Throttlor* (1 to 150% proportional band, manual reset), *Air-O-Line* (1 to 150% proportional band, automatic reset).

PRESSURE

Pressure and vacuum elements—spiral, intermediate-range spring and bellows, low-range spring and bellows, dual spring and bellows for absolute pressure.

Electric control—*Electr-O-Vane*, spst (on-off control), spdt (two-position control), sp3t (three-position control).

Pneumatic control—On-Off. 10% *Throttlor*, *Full Throttlor*, *Air-O-Line*.

75th YEAR PIONEERING THE FUTURE

Honeywell

First in Control

SINCE 1885

Output

summing with ac excitation.

NEW PRODUCTS

NEW PROCESS CHROMATOGRAPH fast enough for closed-loop control.

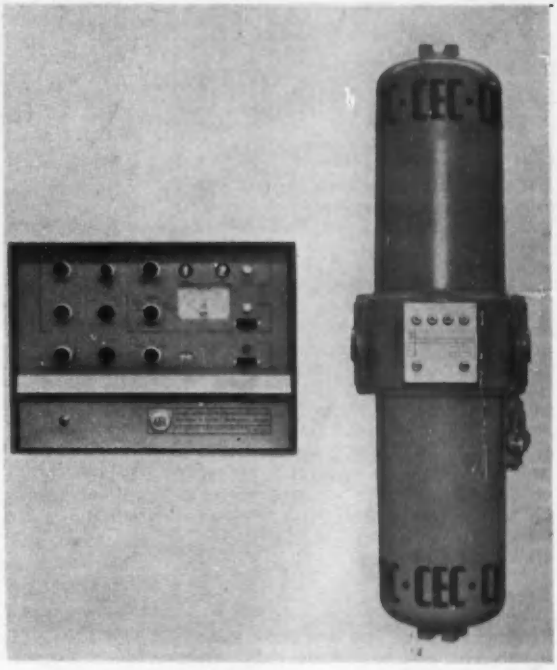


Photo at the right shows the two units which make up the new CEC Type 26-216 Process Chromatograph, a system capable of analyzing liquids, gases, or vapors in 1/20th to 1/50th the time required by conventional chromatographs. This speed permits, for the first time, direct chromatograph control of rapidly changing processes.

System's analyzer unit, far right, features an explosion-proof housing for on-stream installation in hazardous areas. A unique chromatograph package within this housing provides the high speed performance; this consists of a small-volume pneumatic sampling valve, a small-bore packed column, and a fast-response detector.

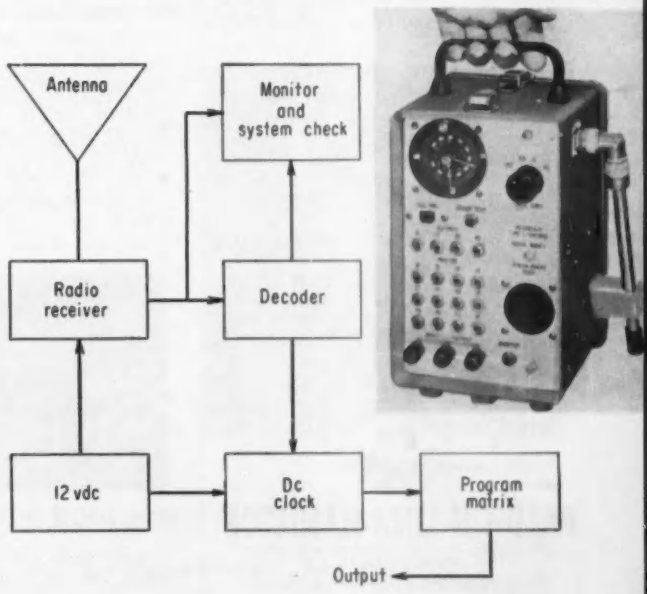
The control unit, containing all operating controls and adjustments, can be located up to 500 feet from the analyzer. A program timer automatically regulates the sequence and timing of up to eight sample streams.

Important design features include: modular construction for maximum flexibility, removable bell housings on the analyzer unit for easy access to all components, independent column temperature control between 50 and 220 deg C, automatic attenuation for selective peak recording, and a front panel switch that permits choice of readout.

Joint effort by CEC and Taylor Instrument has already produced the pneumatic controls for closed-loop use.—Consolidated Electrodynamics Corp., Pasadena, Calif.

Circle No. 280 on reply card

SECONDARY TIME STANDARD offers precisely timed on-off control.

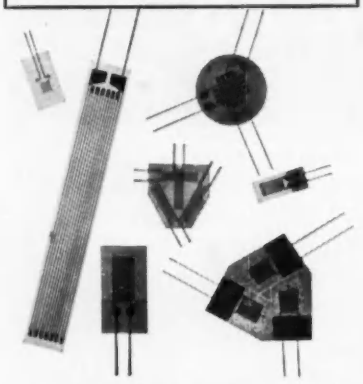


Introduced as the world's first portable, self-powered secondary time standard, this compact instrument houses two major components: a transistorized, crystal-controlled AM receiver with single conversion and a 455-kc i.f., and a special electric clock developed by the Hamilton Watch Co. Its receiver picks up time signals transmitted at 2.5, 5, or 10 mc by government operated stations such as WWV in Belsville, Md. A decoder takes the receiver output and filters out all information except the 1-sec "ticks". These are fed to a pulse generator which provides synchronization for the dc-operated clock.

A set of contacts, using the clock hands and a special circuit board, serves as program matrix. Unit will supply a switching function at 15-, 30-, 45-, or 60-sec intervals, and also at precise 5-min intervals. Accuracy is said to be within 16 sec over a one year period. A special audio amplifier, feeding a small built-in speaker, provides an aural check of receiver performance and a means of obtaining WWV voice and code signals. Complete with batteries, unit weighs 9 lb and will sell for less than $1,000.—Zenith Radio Corp., Chicago, Ill.

Circle No. 281 on reply card

The bonded strain gage makes the difference



SR-4® Transducers and Systems (see opposite page) are used wherever accurate measurement and control of weight, thrust, pressure or torque are required.

Their growing importance on the industrial and military scene is due largely to a unique combination of ruggedness and high accuracy which results from the use of a truly ideal transducer sensing element . . . the SR-4® bonded filament strain gage. This postage-stamp-size device, well known to stress analysts and structural designers as a precision laboratory tool, performs an equally important, and more permanent, function when bonded inside hermetically sealed load cells, pressure cells, and torque pickups.

There it translates minute, force-induced strains into proportional changes in a small electric current flowing through its grid. Detected and amplified, these signals are used to actuate indicators and/or recorders and to control a variety of functions and processes.

Thanks to the bonded strain gage, SR-4® transducers provide advantages unmatched by any other commercially available device.

- High accuracy (to ±0.1% or better)
- Excellent linearity and repeatability
- Rugged construction—no moving parts to wear or maintain
- Hermetically sealed—unaffected by dirt, moisture or corrosive vapor
- Consistent performance, unit to unit
- Infinite resolution
- Maximum flexibility of application and installation

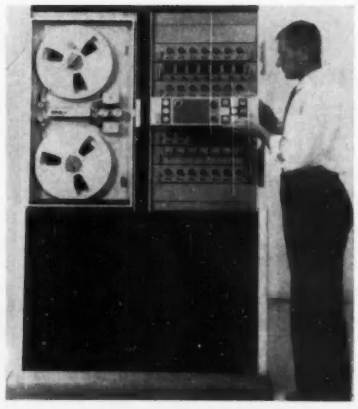
SR-4® Transducers or an SR-4® System may be particularly suited to your requirements. For additional information on weight, pressure, thrust or torque measurement, write Dept. 6-D.

FIRST in force measurement

BALDWIN · LIMA · HAMILTON
Electronics & Instrumentation Division
Waltham, Mass.
SR-4® Strain Gages • Transducers • Systems

NEW PRODUCTS

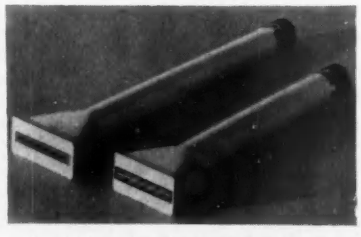
DATA HANDLING & DISPLAY



WILL CHECK MINUTEMAN

Photo above shows a front view of the Ampex FR-600 magnetic tape recorder, the type selected by Boeing Airplane Co. as the primary recorder/reproducer of a telemetry ground station for testing the Minuteman missile. First nine units will have a frequency range of 300 cps to 250 kcps and a tape speed of 60 in. per sec. On later units, bandwidth will be extended to 500 kcps and tape speed to 120 in. per sec. Although the recorder can handle up to 14 tracks on a 1-in. tape, a 7-track, ½-in. tape configuration was selected for this application. Information, both PCM and FM, will be transmitted and recorded at speeds up to 350,000 bits per sec. Units also feature end-of-tape sensing and automatic switching to a second transport for continuous recording. — Instrumentation Div., Ampex Corp., Redwood City, Calif.

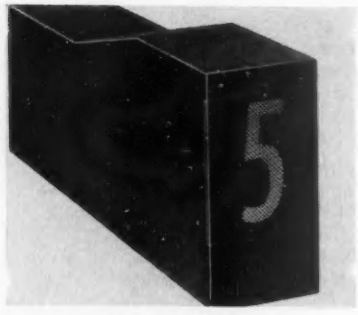
Circle No. 282 on reply card



FOR HIGH SPEED PRINTING

Tradenamed Printapix, these new direct printing cathode ray tubes use a metallic element mosaic target or printing head in place of the phosphor screen usually found on such tubes. The Type L-4013 tube (left) provides for writing complete characters or symbols across the entire head width. The Type L-4016 (right) has a single horizontal line of conductive elements for sequential scan line operation. Both tubes feature a minimum effective printing width of 2.75 in. Conductive elements measure 0.001 in. in diam and are placed on 0.004-in. centers. This produces an element density of 62,500 conductors per sq in.—Litton Industries, Electron Tube Div., San Carlos, Calif.

Circle No. 283 on reply card



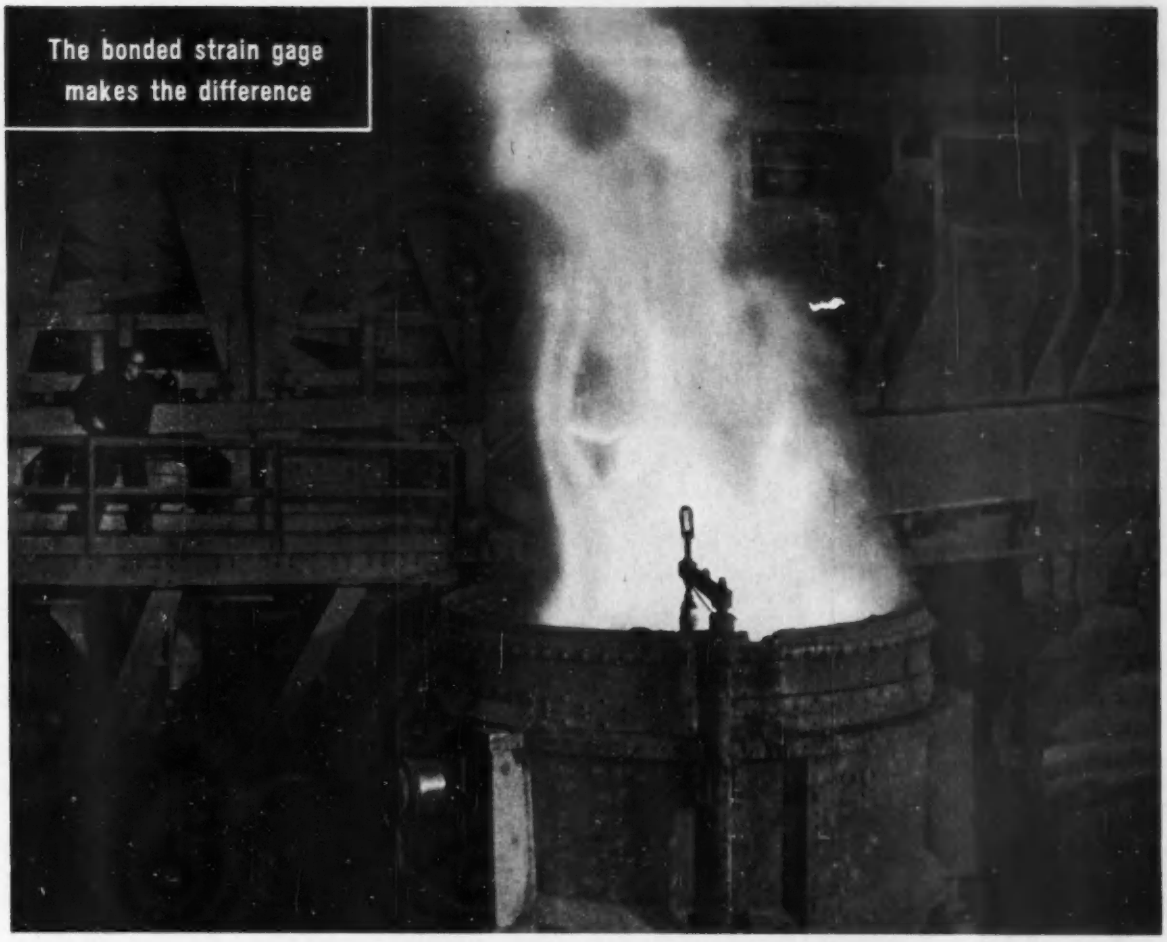
ACCEPTS BCD INPUTS

This Slide Plate in-line readout element will accept any binary coded decimal or Teletype input up to six bits, do its own translating, and display the proper character. Unit can be connected directly to transistor or vacuum tube flip-flops without intermediate buffers or amplifiers and operates on less than 5 mw of signal power. It consists of multiple perforated character plates located between a parallel light source and a lucite viewing screen. When a particular plate is energized, it moves in such a way that a halftone light pattern penetrates its character and is displayed on the viewing screen. A 16-character numeric element sells for about $35; a 40-character alphanumeric element, for about $65.—Industrial Electronic Engineers, Inc., North Hollywood, Calif.

Circle No. 284 on reply card

AUTOMATIC BULK WEIGHER

Designed for multiple ingredient bulk weighing, a new batch weighing system features an accuracy within plus of minus 0.25 percent of calibrated range and a reproductibility of better than one part in 2,000. The system weighs any number of ingredients in a programmed sequence, in any desired proportions. Once system param-



SR-4® system measures ladle additives automatically, helps turn out better ingots

A new means of adding ferro-alloys to steel automatically as it is poured from the ladle is quietly revolutionizing open-hearth steelmaking.

In developing its new Ladle-Additions Feeder, Blaw-Knox engineers turned to Baldwin-Lima-Hamilton for a rugged, accurate weighing system which would operate dependably under conditions where shock, overload and temperature change are the rule rather than the exception. The resulting system, now helping to save production time and improve steel quality in many installations, utilizes four 20,000-lb. SR-4® load cells on each additive bin. They send accurate weight signals to a B-L-H indicating and control system, which automatically feeds additive in precise amounts by weight.

In this, as well as countless other industrial applications, it is the SR-4® bonded strain gage which provides the required accuracy and dependability. Let B-L-H engineers solve your force measurement problems.

Two SR-4® load cells in adjacent bins of a Blaw-Knox Ladle-Additions Feeder. Special B-L-H system filters out vibration and shock signals, sending only precise weight data to instrument panel.

First in force measurement

BALDWIN · LIMA · HAMILTON

Electronics & Instrumentation Division • Waltham, Mass.

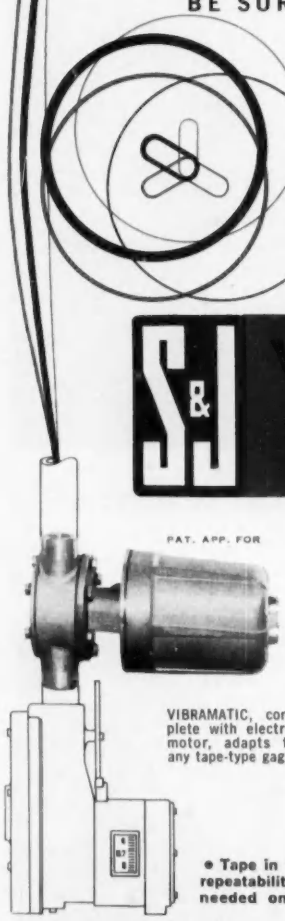
SR-4® Strain Gages • Transducers • Systems

WHERE MAXIMUM ACCURACY IS DEMANDED... S&J BANISHES "GAGE FRICTION"

BE SURE YOUR GAGE READS 29 TRUE 30

1800 RPMs ELIMINATE FRICTION EFFECTS

S&J VIBRAMATIC ELECTRIC TAPE VIBRATOR
MODEL G701



VIBRAMATIC, complete with electric motor, adapts to any tape-type gage.

Gaging tape is "friction-free" for accuracy and repeatability to better than 1/16"—when applied to S&J Gages. For an instant before each reading, VIBRAMATIC puts tape into frictionless "fluid" state. ADAPTS EASILY TO ANY TAPE-TYPE GAGE; automatically energized for remote reading, manually controlled for tankside reading. Separate from gage itself: does *not* paralyze gage if power fails; guided float will *not* sink! S&J engineered for long-life reliability. Motor in explosion-proof aluminum housing. *Details sent immediately upon request.*

• Tape in "fluid state" to eliminate friction • Assures accuracy and repeatability to better than 1/16" • Repeatability 100% • Power needed only at reading time • For remote or tankside gages

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168 CIRCLE 168 ON READER SERVICE CARD

NEW PRODUCTS

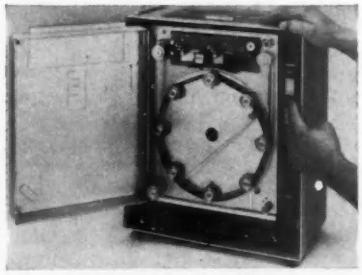
eters have been programmed, operation is fully automatic. Important to the design is the use of unitized, pre-engineered components that can be interchanged with building block simplicity.—Weighing & Control Components, Inc., Hatboro, Pa.

Circle No. 285 on reply card

LOW COST COMPUTER

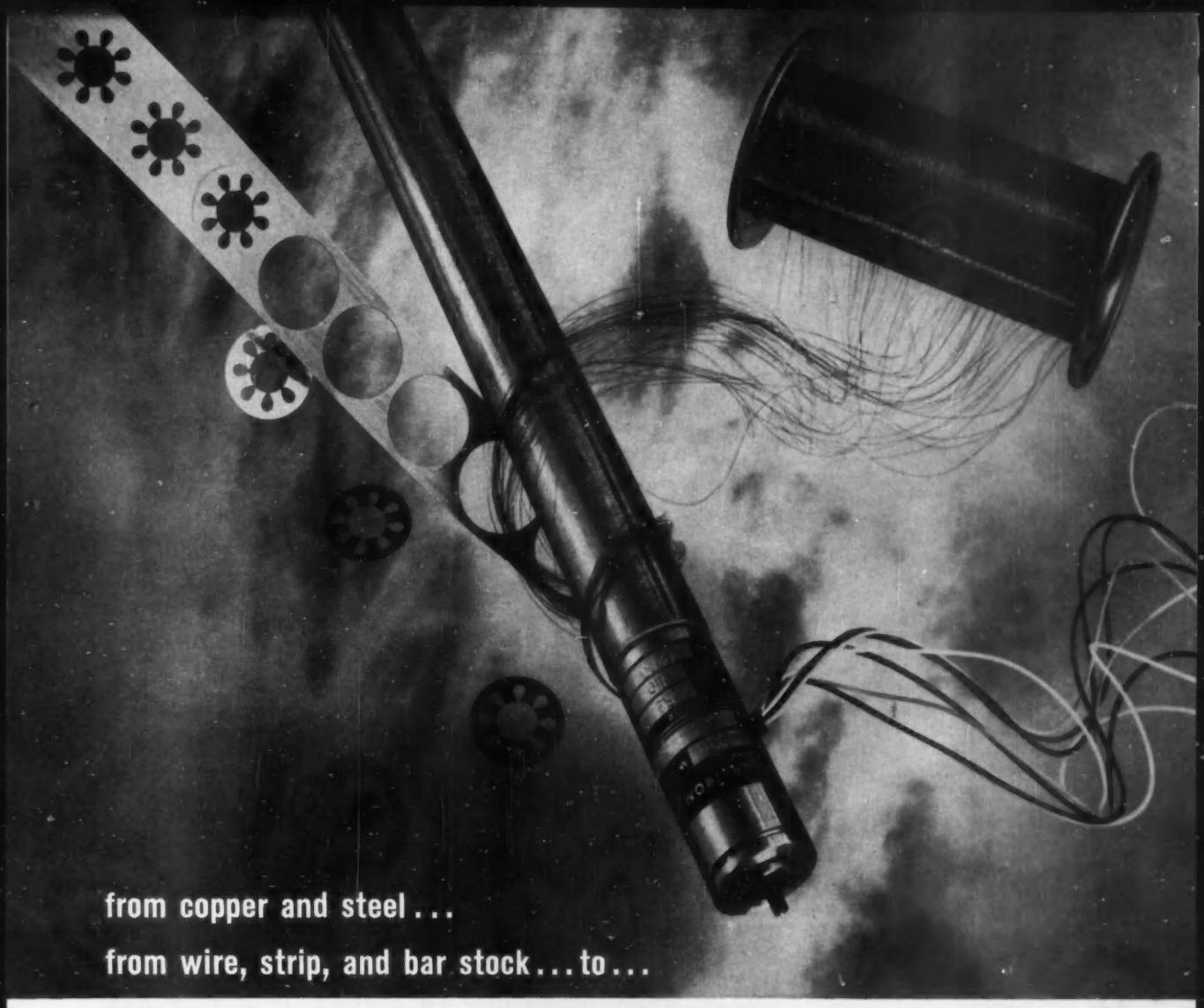
Pictured above is the Model 160 transistorized electronic computer, recently announced entry into the low price field. Designed for broad use in scientific calculations, statistical and business data acquisition, industrial control, and communications, the machine boasts high versatility and speed and can handle 60,000 instructions in a second. Data transmissions take place 65,000 per sec. The 160, a single address computer with high speed parallel mode operation, has storage cycle time of 6.4 microsec, basic add time of 12.8 microsec, information read at 2.2 microsec after start of cycle, and average execution time of 15 microsec per instruction. It sells for $60,000.—Control Data Corp., Minneapolis, Minn.

Circle No. 286 on reply card



TINY TAPE LOOP

Claimed to be the smallest magazine that handles a magnetic tape loop up to 120 ft long, the unit above also provides simple conversion from a laboratory reel-to-reel device to a continuous loop device. The magazine provides an extremely simple tape path



COMPLETE SERVO ASSEMBLIES

We are not an assembly station. We are a manufacturer!

Steel and copper come into our factory. Housings are turned and gears are hobbed from the solid stock. Laminations are stamped from strip steel. Copper is wound right off the reel.

Every operation between raw stock and servo assembly is performed in our own plant, under our own supervision. And because we exercise this complete control over manufacture, we can honestly vouch for the quality and reliability of every motor, generator, synchro, and gear train carrying our name.

Undivided responsibility isn't a new idea by any means, but it is increasingly difficult to find in this age of overspecialization. If you'd care to sample the benefits of this integrated approach, why not call on us now?

SERVO ASSEMBLY – Type 9 motor generator driving two Type 11 CT synchros through a slip clutch and a gear train having ratio of 1500 to 1.

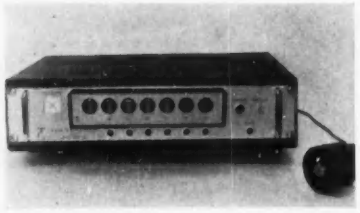
DAYSTROM, INCORPORATED
TRANSICOIL DIVISION WORCESTER • MONTGOMERY COUNTY • PENNSYLVANIA

CIRCLE 169 ON READER SERVICE CARD

NEW PRODUCTS

to allow quick threading; long loops can be swiftly interchanged. Tape widths of ¼, ½, or 1 in. can be accommodated, and all standard speeds from 1⅞ ips can be rapidly selected.—Precision Instrument Co., San Carlos, Calif.

Circle No. 287 on reply card



TRANSISTORIZED CONVERTER

The new system shown above is a transistorized, high speed shaft digitizing system offering resolution of 2,000 counts per rev. It records shaft position on the fly and visually displays the position in decimal digit form on six Nixie readouts. Simultaneously a load driving memory provides output to digital readout devices like tape punches, electric typewriters, etc. Pulses are generated by a Magpi angle pulse generator available with 500, 1,000, or 2,000 counts per rev resolution. Digitizing rate is 20,000 counts per sec.—Data Instruments, Div. of Telecomputing Corp., N. Hollywood, Calif.

Circle No. 288 on reply card

COMPATIBLE TYPEWRITER

The T2PN Printing Reperforator, made by Olivetti, is a full capacity typewriter with a unique feature: in both sending and receiving messages, in addition to punching a conventional ⅞-in., five-channel tape, it prints the typewritten message between the feed holes of the tape. The tapes produced are fully compatible with optical or electronic tape readers. For on-line use for receiving only, the machine rents for $30 per month, sells for $1,555. As an off-line version for tape perforation, a model costs $25 rental per month, sells for $1,260. Full-use model is $37 per month, selling for $1,900. — TELautograph Corp., Los Angeles, Calif.

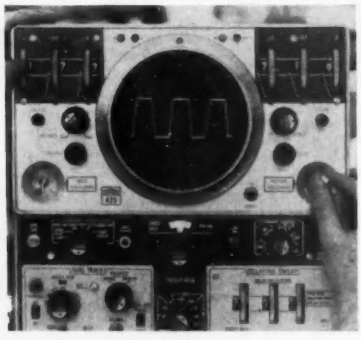
Circle No. 289 on reply card

PLUS . . .

(290) A printed circuit movement used with a ceramic ring coil results in an unusually **slim panel meter** projecting only ¼ in., a development of **Interlab, Inc.**, New York, N. Y. . . . (291) The **Swartwout Div. of the Crane Co.**, Cleveland, Ohio, has introduced an **electronic ribbon indicator** measuring only 2 x 5⅞ in. for use in panels with space limitations or in graphic panel installations. . . . (292) Featuring in-line Nixie readout and modular construction for top flexibility, a new low cost **frequency flow rpm counter** is now available from **Erie Pacific, Div. of Erie Resistor Corp.**, Hawthorne, Calif.

Circle Nos. 290, 291, or 292 on reply card

RESEARCH, TEST & DEVELOPMENT



CUTS READING TIME

Pictured is the front panel of the Du Mont 425, first oscilloscope to feature direct digital readout. In operation the digital display of period and amplitude values is accomplished by manually aligning two measuring dots with the waveform presentation being studied. Three-place readings in volts and seconds are accurate to within 2 percent. Other features include modular construction, a series of interchangeable plug-in amplifiers, and a newly designed cathode ray tube. Useful over a frequency range from dc to

for immediate delivery of

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Newton

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Delburn Electronics, Inc.
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Hudson Radio & Television Corp.
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CIRCLE 170 ON READER SERVICE CARD

GENERAL INSTRUMENT SEMICONDUCTOR DIVISION

JAN TYPE

GENERAL INSTRUMENT SILICON DIODES

1N457
1N458
1N459

When JAN type diodes are required, you can be certain that General Instrument's engineering skills and manufacturing facilities will enable us to deliver them at prices that reflect years of volume production experience.

The General Instrument line of silicon *and* germanium diodes is the most complete available to the industry, with the widest possible range of characteristics. We also make a complete line of medium and high power silicon rectifiers, including all JAN types. Complete information and data sheets are available upon request.

Code No.	Min. Fwd. DC Cur. @ +1V	Max. Rev. DC Cur. @ Test V. 25° C.	Max. Rev. DC Cur. @ Test V. 150° C.	Test Voltage	Max. Inv. Voltage	Min. Breakdown Voltage*	Avg. Fwd. DC Cur. (Max.)
1N457	20 mA	.025 μA	5 μA	60V	60V	70V	75 mA
1N458	7 mA	.025 μA	5 μA	125V	125V	150V	55 mA
1N459	3 mA	.025 μA	5 μA	175V	175V	200V	40 mA

*Reverse voltage at which a reverse current of 100 uA flows.
All ratings and characteristics are at 25° C. unless otherwise noted.
Operating temperature range −80° C. to +200° C.

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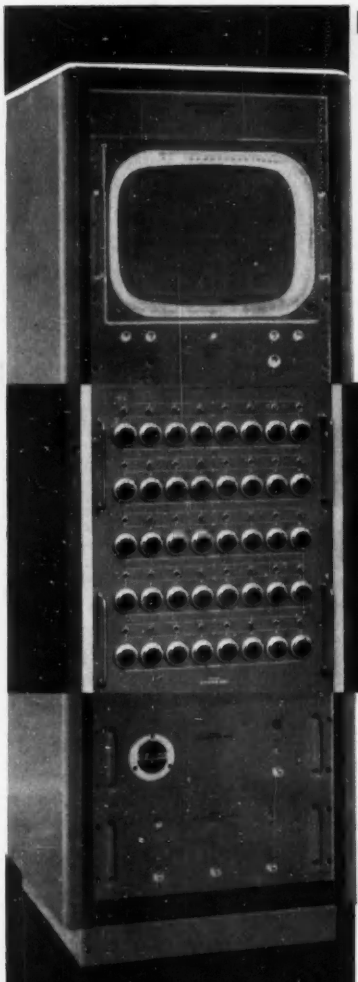


IN ONE ITT BAR-GRAPH OSCILLOSCOPE

40 CHANNEL READ-OUT

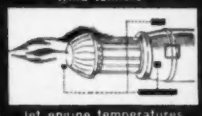
This single, ultra-sensitive display system does the work of 40 separate meters . . . provides quick-look convenience and accuracy for innumerable monitoring applications. Any 40 variables—related or unrelated—that can be converted into electrical signals can be studied, measured, and compared at once on the 17-inch scope of the Model 40BG.

Output of each of the channels is scanned ten times per second by means of a synchronous motor driven switch. Ultra-stable circuits provide maximum accuracy . . . line voltage variations cannot affect performance.

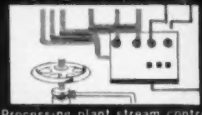
For complete information contact your ITT Instruments representative, or write us for Data File CE-1022-1.

Typical monitoring applications:

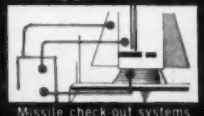
Wind tunnels



Jet engine temperatures



Processing plant stream control



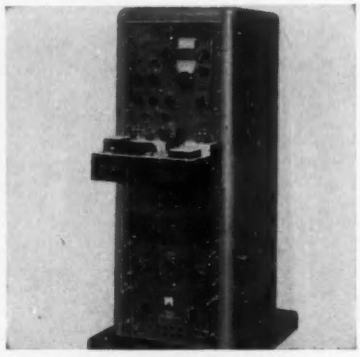
Missile check-out systems

ITT Industrial Products Division
International Telephone and Telegraph Corporation
15191 Bledsoe Street • San Fernando, Calif. • EMpire 7-6161
static power conversion • instruments • closed circuit television

NEW PRODUCTS

60 megacycles, the 425 requires 1,000 watts at 115 volts, 60 cps.—Allen B. Du Mont Laboratories, Inc., Clifton, N. J.

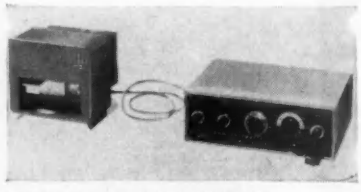
Circle No. 293 on reply card



ANALYZES AUTOMATICALLY

The D-940-A Auto Analyzer shown above incorporates additional automatic facilities into the Muirhead-Pametrada Wave Analyzer to provide analysis of all types of complex waveforms. Two analyses are available: amplitude/frequency analysis of steady signals and amplitude/frequency/time analysis of nonsteady signals. Results are plotted on a recorder as X-Y or X-Time charts. Frequency range is 10 cps to 19 kcps covered in four bands. Complete setup with power supplies and recorder is $12,500.—Muirhead Instruments, Inc., New York, N. Y.

Circle No. 294 on reply card



ACCURATE WEIGHING

Laboratory accuracy under production conditions is what the maker claims for this new Model RM Automatic Electrobalance. Suitable for weighing a wide variety of small components and materials, the instrument has two ranges, 0-20 and 0-100 mg. Sensitivity on the 0-20 range is 0.002 mg; on the wider range, 0.01 mg. Instrument consists of a weighing unit cable-connected to a control unit. It operates on the null-balance principle, the output of a phototube being balanced

recti/riter® recorders prove what every engineer knows . . . SIMPLICITY MEANS RELIABILITY

What simpler and more reliable actuating device can you employ in an amperage-voltage-frequency recording instrument than a d'Arsonval galvanometer . . . a trouble-free horseshoe magnet and a coil of wire? The same is true of the exclusive "recti/rite"® system . . . a simple, shock resistant trigonometric linkage that straightens the arc described by the galvanometer metering arm, changing curvilinear motion to rectilinear motion.

All the other "recti/riter" recorder features which contribute to this instrument's multi-industry acceptance and hardworking reliability are equally simple: The optional a-c or d-c drives couple directly with chart speed change gears to allow ten chart speeds; all routine operations and adjustments are performed "up front"; the non-corrosive, honed metal alloy pens, closed ink system, and large capacity ink well give you long, consistent writing performance.

With all their simplicity and reliability, "recti/riter" recorders are offered in extremely wide and useful Basic Recorder Ranges (Dual channel recorders offer combination of any two ranges):

Two Cycle Pen Response

D-c Milliampere Ranges ..... ¼ ma to 100 ma
A-c Ampere Ranges ..... 0.25 A to 25 A
D-c Ampere Range ..100 mv for use with standard shunts
Expanded Scale A-c Voltage Ranges ..... 80-130 V, 160-260 V, 320-520 V
A-c and D-c Voltage Ranges ..... 10 V to 1000 V
Frequency Ranges ..... 50, 60, 400 cps

Five Cycle Pen Response

D-c Milliampere Range ..... 5 ma

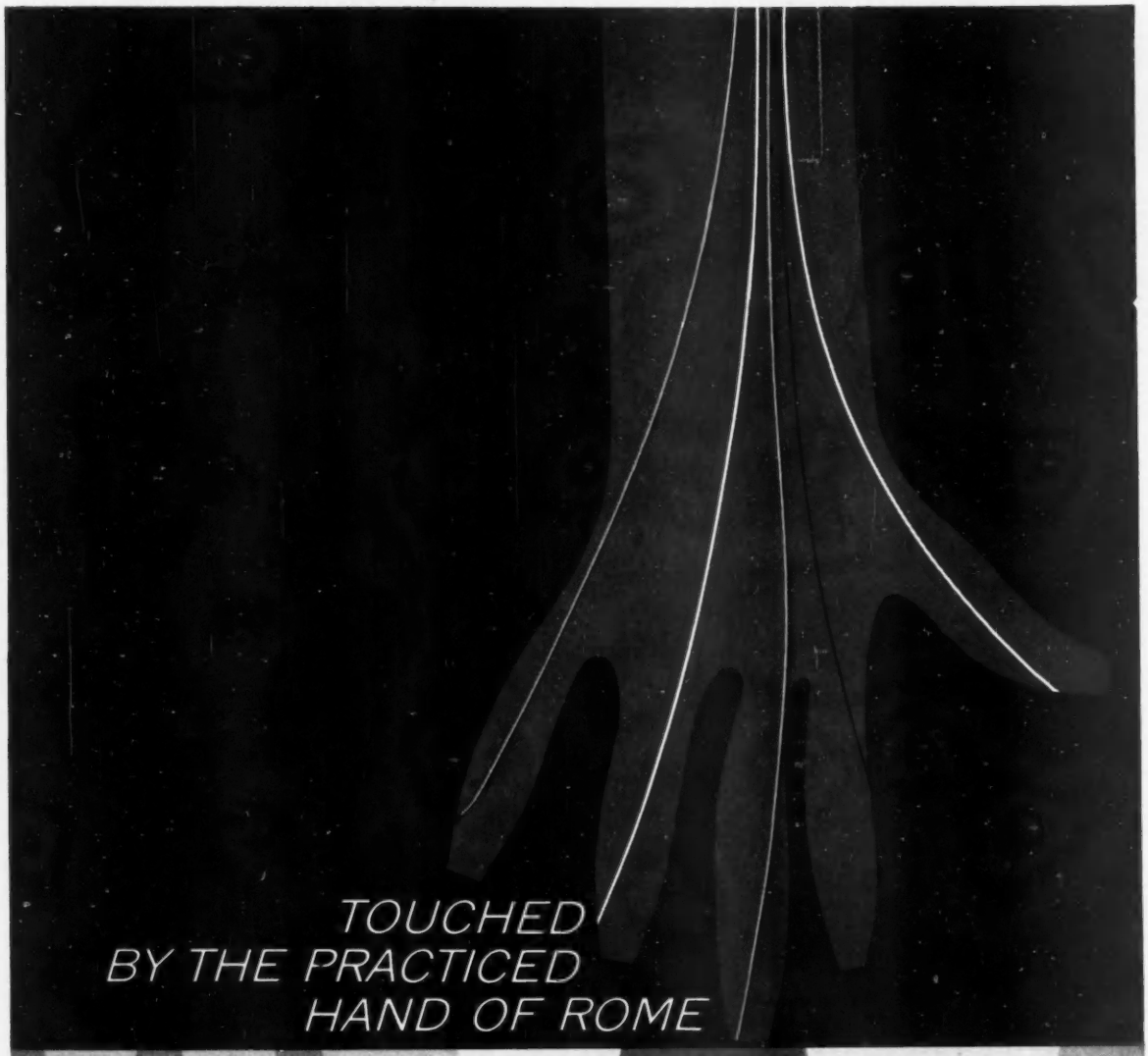
Ask the TI engineer about *customized* recorders for your OEM applications. Don't settle for any recorder until you know all the facts on the complete "recti/riter" recorder line.

TEXAS INSTRUMENTS
INCORPORATED
GEOSCIENCES & INSTRUMENTATION DIVISION
3609 BUFFALO SPEEDWAY • HOUSTON 6, TEXAS • CABLE: TEXINS

The proved "recti/riter" recorder is a companion to the new "servo/riter"* recorder.

*"servo/riter" is a trademark of Texas Instruments

CIRCLE 173 ON READER SERVICE CARD



Univac Reservations Control Center for Eastern Air Lines provides fast service in confirming reservations between agents. Installation uses Rome control cable exclusively.

How to pick one seat in a million—reliably!

This remarkable Univac equipment locates one seat in a million in seconds to confirm reservations at Eastern Air Lines' new electronic reservation center in New York City.

Failure of any single component would seriously impair the effectiveness of the entire system. That is why all of its complex control-panel connections are made with Rome control cable—insulated and jacketed with Rome Synthinol (PVC) thermoplastic compound for high resistance to oils, acids, alkalies, grease, gasoline and flame.

The Univac links 135 Eastern Air Lines reservations and ticket agents in the New York area, as well as other agents in stations from Boston to Washington. It can store data on one million airplane seats up to one year in advance.

Though constructed with 75 conductors, this specially designed Rome control cable is slim and trim for quick and easy connections even in "tight" spots. Its rugged construction makes it ideal where maximum reliability is necessary.

Rome can help you solve control-panel problems on your job, too. If you need a special cable, as Eastern Air Lines did, Rome's engineers will design and build whatever your equipment requires. If standard cable is adequate for the job, Rome has a wide and complete line for you to choose from. Get in touch the next time you need help: Rome Cable, Dept. 104, Rome, New York.

ROME CABLE
DIVISION OF **ALCOA**

CIRCLE 175 ON READER SERVICE CARD

NEW PRODUCTS

by an electromagnetic moment. Balancing voltage may be applied to a voltmeter or chart recorder calibrated directly in milligrams.—Cahn Instrument Co., Paramount, Calif.

Circle No. 295 on reply card

FLAT FROM DC TO 15 KC

Pictured here is the new TDC-1, a low noise, low level dc preamp designed for use with strain gages, bolometers, resistance thermometers, or thermocouples. Its balanced push-pull transistor circuit will drive oscilloscopes, VTVM's, galvanometers, and less sensitive pen recorder amplifiers. Voltage gains of 10 and 30 are provided, as well as a maximum gain position. Maximum input signal is 100 mv for 1 percent linearity. Complete with self-contained battery, unit is priced at $75.—Ramapo Instrument Co., Inc., Bloomingdale, N. J.

Circle No. 296 on reply card

PORTABLE INDICATOR

Aside from its ability to indicate displacement, acceleration, force, pressure, and other quantities that can be sensed by a differential transformer, this Model 300BF indicator also provides a demodulated output, flat to 500 cps, for operating cathode ray and recording oscillographs. Static, slowly changing, and average values may be read directly from its 10-in. Weston panel meter. Accurate to within 1 percent, the device will resolve 0.000005 in. of core displacement. It sells for $395.—Daytronic Corp., Dayton, Ohio.

Circle No. 297 on reply card

SPOTS MEMORY FLAWS

A new device to automatically locate defects in coincident core memories is called a memory exerciser. The Type 1513 will test memory systems up to 128 x 128 planes by reading in and reading out a pattern of information. It lights an indicator bulb on a panel if it detects a core dropping or picking up an extra "one". Variable timing cycles operate down to 5 microsec.—Digital Equipment Corp., Maynard, Mass.

Circle No. 298 on reply card

MEASURES RESOLVER ERROR

The new Model RF-1 resolver function bridge displays directly, as a percentage error, deviation from the ideal sine or cosine output function of computing resolvers. It will test any resolver no matter what its other electrical and physical characteristics. The developers claim that less than 2 min. are needed to fully measure and record each resolver winding compared to 45 min by older methods. The device has a range of zero to 360 deg in 5-deg increments, instrument error of 0.002 percent or less, and is 19 x 8¾ x 12 in. (w,h,d).—Theta Instrument Corp., Saddle Brook, N. J.

Circle No. 299 on reply card

INDIRECT BUT ACCURATE

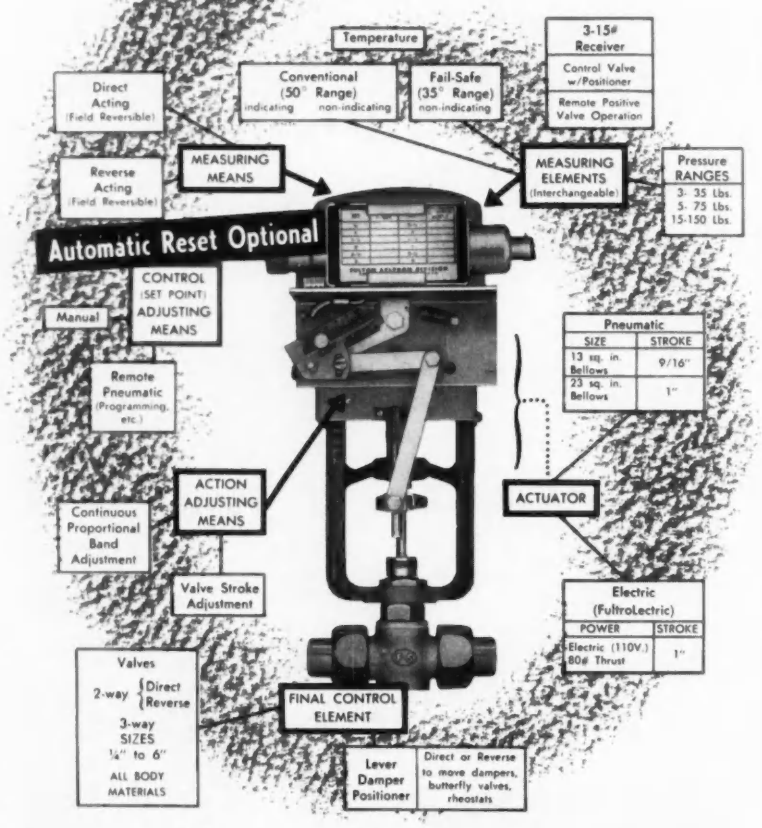
A new corrision measurement probe that can measure hard-to-detect liquid or gaseous contaminants is now available. By measuring the change in resistance of a 2 to 50 millionths of an in. thick metal film resulting from corrosion of the film, the probe effectively measures the corrosion-causing contaminants present.—Crest Instrument Div., Magna Products, Inc., subsidiary of Thompson Ramo Wooldridge, Inc., Canoga Park, Calif.

Circle No. 300 on reply card

GREATEST FLEXIBILITY IN POWERED CONTROLLERS!

THE NEW FultroMatic® 3-IN-1

Controller-Positioner-Valve



Adding the precision performance of pneumatic control to the ruggedness and simplicity of our famous self-ops, the "one-package" FultroMatic gives positive control for process temperatures or pressures, with wide choice of ranges . . . at about half the cost of 2- and 3-unit systems. For complete data, write today for Bulletin GW-755. **Fulton Sylphon Division, Robertshaw-Fulton Controls Co., Knoxville 1, Tennessee.**

Robertshaw® MR. CONTROLS

NEW PRODUCTS

AIDS CALIBRATION

The rictometer, a compact device designed for use in calibrating gyro-stabilized compass system transmitters, eliminates more than 99 percent of the effect of the earth's horizontal magnetic field, while creating a known horizontal field adjustable through 360 deg. Low in cost, the device is also insensitive to other external magnetic fields and can be used in almost any shop or laboratory location. With its current off it simulates the earth's magnetic field at an altitude of at least 35,000 miles. This suggests its use in calibrating space-bound magnetometers as well.–General Electric Co., Schenectady, N. Y.

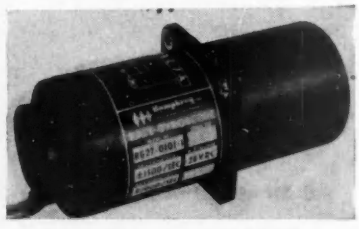
Circle No. 301 on reply card

PLUS . . .

(302) Quick determinations of surface and immersion temperatures are yielded by a new **probe-type thermometer** introduced by **Ameresco, Inc.**, Little Falls, N. J. . . . (303) New from **Kin Tel Div. of Cohu Electronics, Inc.**, San Diego, Calif., is an accurate, stable **ac voltage standard** giving 1 to 501 volts rms at 5 amps up to 5 volts and at 25 watts above 5 volts. . . . (304) Pulse repetition rates continuously variable from 1 cps to 10 Mcps are available in a new high speed **pulse generator** from **Rutherford Electronics Co.**, Culver City, Calif.

Circle Nos. 302, 303, or 304 on reply card

PRIMARY ELEMENTS & TRANSDUCERS



GIVES TWO RATE OUTPUTS

Shown is a miniaturized dual-axis rate gyro, designed to save space and reduce costs in missile and aircraft systems. Only 4 in. long by 1¾ in. in diam, the instrument can be supplied

GD700 SERIES
GAS-O-DOME REGULATORS

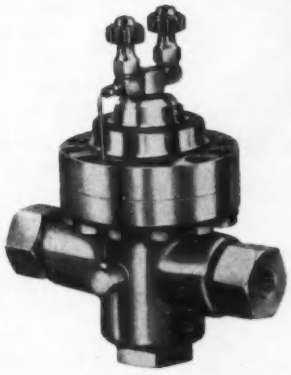
Models in bronze or stainless steel
Pilot operated type
Max. inlet: 7000 to 10,000 psig.
Outlet range: 10-150 to 400-7000 psig.
Flows to 250 scfm.
Low torque: 35 inch-lb. at 7000 psig.
Panel mounting
Bulletins R12 and R18.

BPR SERIES
BACK PRESSURE REGULATORS

Models in bronze or stainless steel
Adjustable relief ranges: From 25-500 psig. to 2000-10,000 psig.
Panel mounting
Bulletin R19

LR SERIES LOADER REGULATORS

Models in bronze or stainless steel
Max. inlet: 7000 to 10,000 psig.
Outlet range: 5-200 to 200-10,000 psig.
Flow: 10 scfm.
Low torque: 35 inch-lb. at 7,000 psig.
60 inch-lb. at 10,000 psig.
Panel mounting
Bulletins R11 and R17



GD90, GD100A AND GD200A
SERIES GAS-O-DOME REGULATORS

Models in bronze or stainless steel
Compensated, high-flow type
Max. inlet and outlet: 6000 psig.
Flows to 80,000 scfm.
Remote control and/or panel mounting provisions
Bulletin R18

LV-10 LOADER VALVE

Made in bronze only.
Inlet and outlet: 7000 psig.
Flow: 10 scfm.
Fast finger-tip control:
30° clockwise, loads;
30° counter-clockwise, bleeds.
Panel mounting
Bulletin LV-10

GD60 AND 80 SERIES
GAS-O-DOME REGULATORS

Models in bronze
(stainless steel on request)
Inlet and outlet range: 2500 to 10,000 psig.
Flows to 1500 scfm.
Remote control and/or panel mounting provisions
Bulletin R10A

VICTOR High pressure gas controls

Victor offers you choice of these and many other gas regulators for a wide variety of applications.

All come cleaned for oxygen service; LOX cleaned when specified. Operating temperature ranges: —67° F. to +250° F. (storage —80° F.) Modifications for special applications. Write now for Victor High Pressure Regulator bulletins and Regulator Inquiry Form 361A.

Mfrs. of high pressure and large volume gas regulators; welding & cutting equipment; hardfacing rods; blasting nozzles; cobalt & tungsten castings; straight-line and shape cutting machines.

VICTOR EQUIPMENT COMPANY MISSILE DIVISION

63

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CIRCLE 177 ON READER SERVICE CARD

J. C. Menzies & Co., Wholly-Owned Subsidiary

A GOOD RESOLUTION ON TAPE—

Tape high frequencies, whip the dropout problem with "SCOTCH" BRAND High Resolution Tapes

RIGHT HANDS UP, GENTLEMEN? Then repeat this phrase: "We resolve to get the tape that gets all the high frequencies—'SCOTCH' BRAND High Resolution Tape."

All levity aside, there's no need to settle for second-best. With "SCOTCH" BRAND Tapes 158 and 159 you get sharp resolution in high frequencies, good low frequency response—plus the consistent performance of a uniform tape.

Since "SCOTCH" BRAND high potency oxides are more efficient than ordinary oxides, a thinner coating can be applied to the polyester backing, and the sensitivity at short (1 mil) wave lengths is still about 3½ db greater than that of ordinary oxides. This thinner coating means a more flexible tape, permitting the intimate tape-to-head contact so necessary to sharp resolution in the higher frequencies. Thanks to "SCOTCH" BRAND silicone-lubricated binder system, backing and oxide are locked together as a *system*. Tape passes over heads friction-free, with even motion, minimizing phase and frequency shift distortion.

You can pack more pulses per inch, and get either standard or extra playing time with "SCOTCH" BRAND High Resolution Tapes. Your dropout count is lower because uniformity is higher. Only "SCOTCH" BRAND can draw on 3M's more than 50 years of experience in precision coating techniques. The result is a consistent tape with a uniform coating you can depend on for reliable performance.

"SCOTCH" BRAND High Resolution Tapes meet your need for top high-frequency response even in pulse code modulation (PCM) and pre-detection (video) applications; so switch now from tapes that may well be made obsolete by new instruments.

Whatever your application—data acquisition, reduction, or control programming—experienced "SCOTCH" BRAND technology has a dependable tape for the job. Sandwich Tapes 188 and 189 cut headwear, eliminate oxide rub-off, last 10 times longer than ordinary tapes. New Heavy Duty Tapes 198 and 199 give long wear, minimize static charge build-up. High Output Tape 128 gives top output in low frequencies, even at temperature extremes. And "SCOTCH" BRAND Standard Tapes 108 and 109 remain the standard for instrumentation.

Your nearby 3M Representative serves as a convenient source in all major cities. For details consult him or write Magnetic Products Div., 3M Company, Dept. MBS-40, St. Paul 6, Minn.

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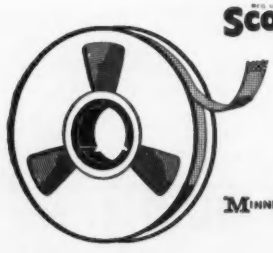


SCOTCH BRAND MAGNETIC TAPE

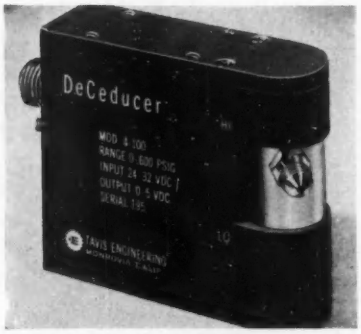
FOR INSTRUMENTATION

MINNESOTA MINING AND MANUFACTURING COMPANY
... WHERE RESEARCH IS THE KEY TO TOMORROW

3M COMPANY

in rate ranges from 50 to 2,000 deg per sec. Hermetically sealed in a steel case with center flange mount, it contains an independent potentiometer pickoff for each axis. All metal pot construction permits high level excitation and provides a powerful output signal. Each pot will dissipate up to 2 watts. Excitation voltages to 60 volts may be used. Unit is furnished with either a 12- or 28-vdc motor.–Humphrey, Inc., San Diego, Calif.

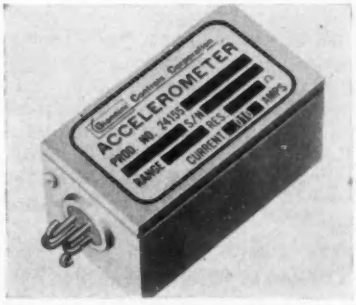
Circle No. 305 on reply card



WIDE RANGE PICKUP

Specifically designed for aircraft, missile, and test applications, the Model 4-100 DeCeducer is a rugged, completely flexible dc-to-dc pressure transducer, covering ranges from 0-5 to 0-5,000 psi, absolute, gage, or differential. The instrument weighs just 12 oz and features an extremely stable output for input voltages between 24 and 32 vdc.–Tavis Engineering, Monrovia, Calif.

Circle No. 306 on reply card



IDEAL FOR TELEMETERING

Just 0.8 in. square by 1½ in. long, this Model 24155 subminiature dc accelerometer can be furnished with a potentiometer resistance of from 2,000 to 5,000 ohms with standard acceleration ranges of from ±2 to ±25 g's. Linearity, hysteresis, and repeatability of the fluid damped unit are within 1 percent. A high natural frequency combined with its high electrical output makes the unit well suited for telemetering applications. – Giannini Controls Corp., Pasadena, Calif.

Circle No. 307 on reply card

(308) A new line of linear variable **differential transformers,** with total linear strokes of from 1 to 4 in., has recently been announced by **Pacific ElectroKinetics,** Glendora, Calif. . . . (309) Working with the Army Ordnance Corps, **Electro-Optical Systems, Inc.,** Pasadena, Calif., has developed a new whisker-sized **semiconductor strain sensing element** with an ultimate gage factor of 175.

Circle Nos. 308 or 309 on reply card

CONTROLLERS, SWITCHES & RELAYS

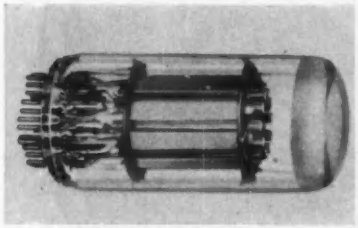
ACCELERATION SENSITIVE

A new miniature, bidirectional, single-axis switch capable of closing electrical circuits in response to a preset acceleration level will automatically reset itself when the acceleration drops below that same value. Hermetically sealed, the unit weighs just 1 oz and is particularly suited for aircraft and missile applications.

Characteristics:

Range: ± 10 to ± 30 g's
Switch: spdt, normally open
Contact ratings: 100 ma each
Accuracy: within 5 percent
Repeatability: within 0.5 g
–Instruments Div., W. L. Maxson Corp., New York, N. Y.

Circle No. 310 on reply card



CUTS COST IN HALF

This BEAM-X switch, Type BX-1000, represents the first of a new

REMEMBER!

For immediate information on "SCOTCH" BRAND Instrumentation Tapes, contact your nearest 3M branch office:

ATLANTA, GA. — 732 Ashby Street, N.W. Telephone: TRinity 6-4401

BEDFORD PARK, ILL. (Chicago Office)—6850 South Harlem Avenue, Argo Post Office, Telephone: GLobe 8-2200 (Chicago—LUdlow 5-7800)

BUFFALO, N.Y.—330 Greene Street (P. O. Box 2012, Zone 5), Telephone: BAiley 5214

CINCINNATI, OHIO—4835 Para Drive, Telephone: ELmhurst 1-2313

CLEVELAND, OHIO—12200 Brookpark Road, Telephone: CLearwater 2-4300

DALLAS, TEXAS—2121 Santa Anna Avenue (P. O. Box 28158), Telephone DAvis 7-7311

DETROIT, MICH.—411 Piquette Avenue, Telephone: TRinity 5-7111

HIGH POINT, N. C. — 2401 Brevard Street (P. O. Box 151), Telephone: 3496

HONOLULU, HAWAII—1410 Kapiolani Boulevard, Telephone: 996-483

LOS ANGELES, CALIFORNIA—6023 South Garfield Avenue, Telephone: RAymond 3-6641

NEWTON CENTER, MASS. (Boston)—1330 Centre Street, Telephone: DEcatur 2-9810

PHILADELPHIA, PENN. — 5698 Rising Sun Avenue, Telephone: PIlgrim 2-0200

RIDGEFIELD, NEW JERSEY (New York)—700 Grand Avenue, Telephone: WHitney 3-6700 (N.Y.—OXford 5-5520)

ST. LOUIS, MISSOURI—10725 Baur Boulevard, Telephone: WYdown 1-1320

ST. PAUL, MINNESOTA—367 Grove Street, Telephone: PRospect 6-8511

SEATTLE, WASHINGTON—3663 First Avenue South, Telephone: MUtual 2-5550

SOUTH SAN FRANCISCO, CALIFORNIA—320 Shaw Road, Telephone: PLaza 6-0800

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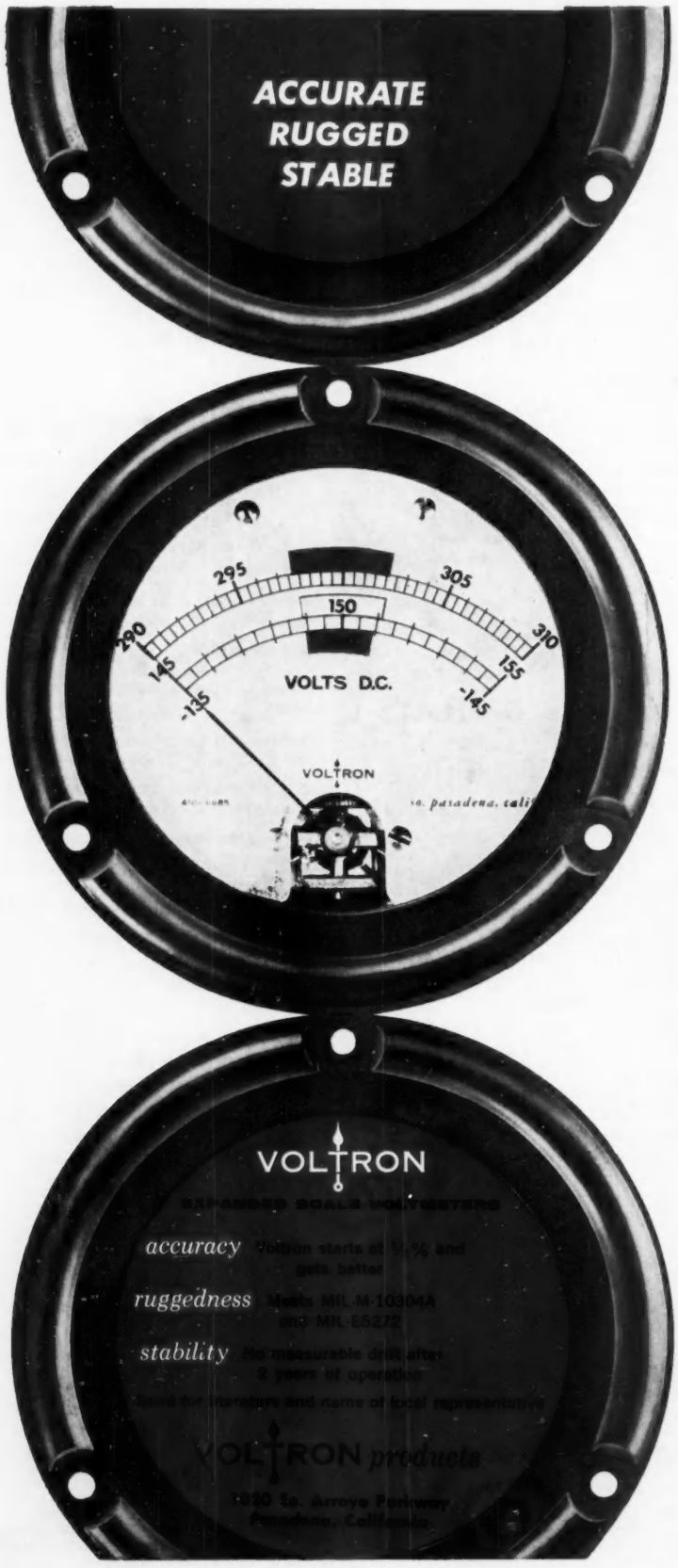
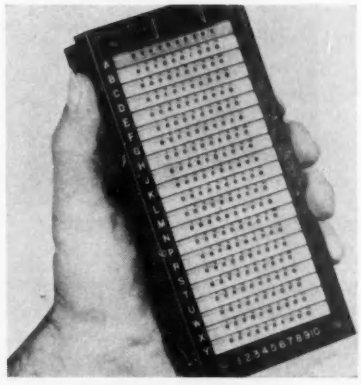


series of decimal electronic switches. Functionally similar to its predecessor, the Beam Switching Tube, the BX-1000 features a radically different design and a much lower price. Small rod magnets within a vacuum control the position of an electron beam to any one of 10 positive switching elements. There are no heavy external magnets or magnetic shields. Unit operates from a wide range of *B*-plus voltages, provides constant current outputs, and is capable of switching speeds in excess of 1 megacycle either sequentially or at random. Price in small quantities is said to be less than $25.—Electronic Tube Div., Burroughs Corp., Plainfield, N. J.

Circle No. 311 on reply card



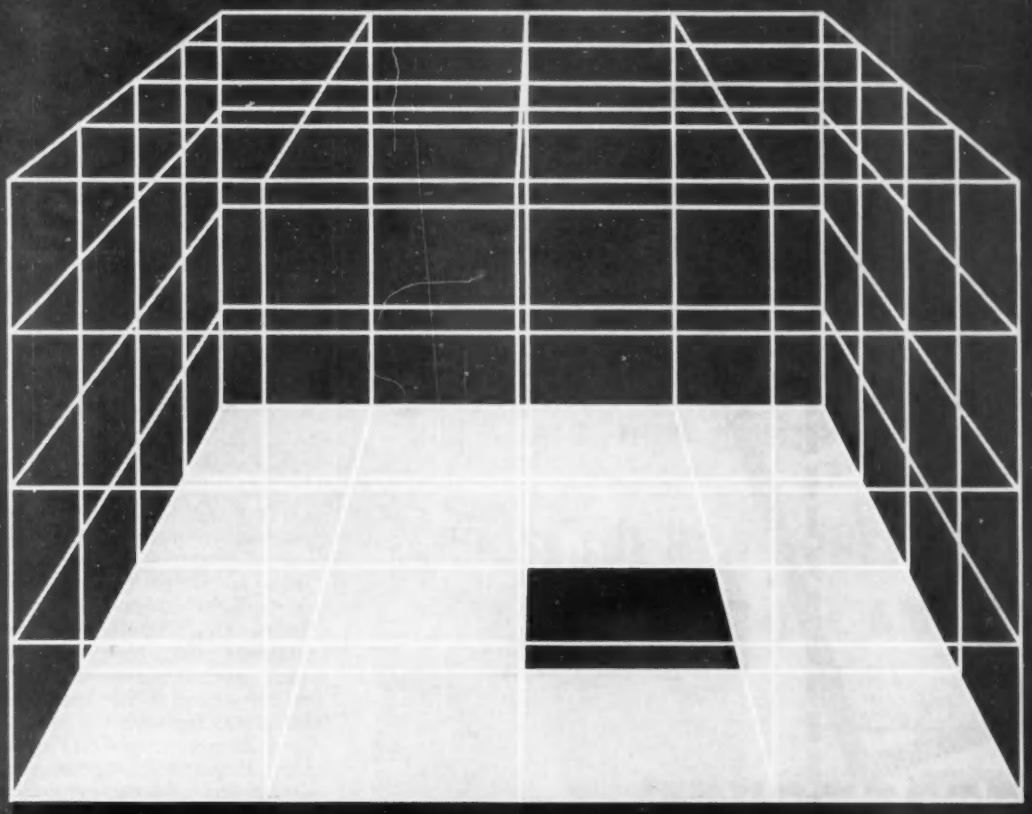
FASTER STATIC CONTROL

Switching rates up to 25,000 per sec are featured in a complete new line of compact, color-coded static control components called Norpaks. Using transistor NOR elements exclusively, Norpak systems can perform any of the basic logic functions (AND, OR, NOT, and memory). Units can be purchased separately or in completely engineered systems. Optional monitor lights provide a visual indication of performance, and a simple dynamic sequence tester checks operation of individual NOR elements.—Square D Co., Milwaukee, Wis.

Circle No. 312 on reply card

COMPACT CONTROLLER

A new proportional-pulse modulating controller, designed to operate dc electric valves or positioners on aircraft, occupies less than 28 cu in. and weighs approximately 1.1 lb. Unit requires a 115-volt, 400-cycle supply and uses



Selective Solutions in Electro-Mechanics

For the past 14 years, Western Design has been a prime supplier of custom-built rotary and linear electro-mechanical devices... for aircraft, missile and ground handling application. From the more than 1000 designs on hand, one can be quickly, economically, reliably customized to your specific need... be it a timer, programmer, motor, actuator, hoist, blower, instrumentation device or similar application. ■ The proven know-how of hundreds of in-use products... the extensive inventory of on-hand drawings... the continuous company-sponsored R&D programs... all add up to quicker electro-mechanical solutions for you at less cost. ■ So before you design, check Western Design — through your local Western Design representative or by writing us directly for Data File CE-1038-1.

USI

Western Design

DIVISION OF U.S. INDUSTRIES, INC.

SANTA BARBARA AIRPORT, GOLETA, CALIFORNIA

CIRCLE 181 ON READER SERVICE CARD

critical...

critical to many of the most complex military and industrial control systems are Diehl Servomotors and electromechanical components.

DIEHL AC Servomotors are made in output ratings ranging from 1 to 750 watts . . . in 60 cycle frequencies for land and shipboard operation . . . 400 cycle frequencies for airborne service. DC Servomotors produced by Diehl are available in ratings up to 2½ HP . . . and in combination with DC Tachometers.

Diehl produces an extensive line of high precision equipment: servomotors, resolvers, potentiometers, generators, servo amplifiers. In sum, the range of instrument servo components for automatic control. Major development work is in progress.

Whatever your critical need — development assistance or actual electromechanical hardware — you'll find that they'll best be filled at Diehl.

For complete details on this important source of service and supply, write for the Diehl facilities brochure.

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A SUBSIDIARY OF THE SINGER MANUFACTURING COMPANY
Somerville, New Jersey

SINGER®

†A Trademark of THE DIEHL MANUFACTURING COMPANY *A Trademark of THE SINGER MANUFACTURING COMPANY

NEW PRODUCTS

a miniaturized magnetic amplifier for its input stage. Pulse forming circuits and a pair of silicon controlled rectifiers provide a pulse output to the field winding of the actuator or valve motor. Pulse duration is proportional to the error signal. Units are already on order for positioning and temperature control applications.–AiResearch Div., Garrett Corp., Los Angeles, Calif.

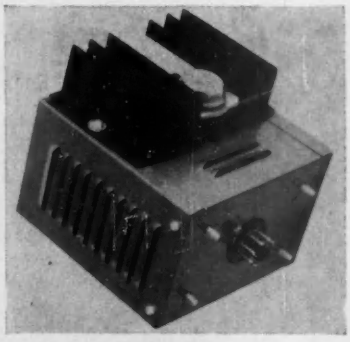
Circle No. 313 on reply card

PLUS . . .

(314) A new family of 30-amp, 115-vac **mercury relays** for ultrahigh and normal temperature requirements has been introduced by **Sorrels-Johnson** Corp., Beverly, Mass. . . . (315) **Micro Switch Div., Minneapolis-Honeywell Regulator Co.,** Freeport, Ill., now offers a **plug-in limit switch** with a pair of two-circuit double-break switches for controlling as many as four isolated circuits. . . . (316) **Photoswitch Div., Electronics Corp. of America,** Cambridge, Mass., recently announced a completely new line of **transistorized photoelectric controls** for general industrial use.

Circle Nos. 314, 315, or 316 on reply card

POWER SUPPLIES

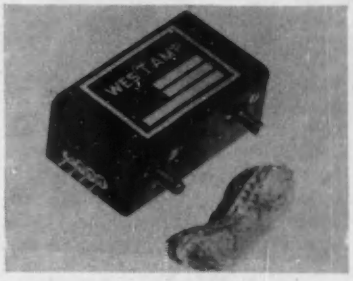


PLUG-IN POWER

Pictured is one of four new plug-in solid state power supplies for applications requiring a reliable compact source of dc power. Output voltages from 1 to 101 volts are available and adjustable over a 1-volt band. Maximum current range is from 0.1 to 2.0 amp. All units operate on an input voltage of from

105 to 125 volts, 50-400 cps. For a full line or load step change, response time is less than 50 micro sec. Both line and load regulation are within 0.1 percent or 20 mv, whichever is greatest.—Deltron Inc., Philadelphia, Pa.

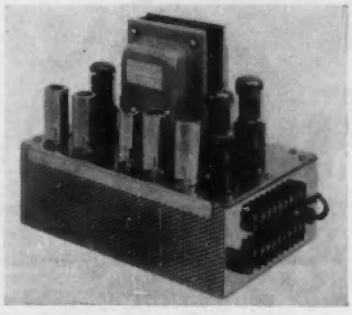
Circle No. 317 on reply card



DC TO SQUARE WAVE

With a total volume of just over 2½ cu in., this Model P303 static inverter operates on a 28-vdc input and supplies up to 60 watts of output power in the form of a 400-cycle square wave. A frequency stability of within 1 percent over a wide temperature range makes the unit ideal for operating gyro and recorder motors. It weighs 3 oz and boasts an effciency of 95 percent.—Westamp, Inc., Los Angles, Calif.

Circle No. 318 on reply card



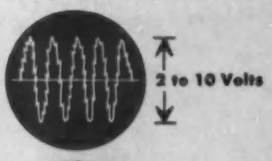
CHOICE OF OUTPUTS

Available either as a bench module for laboratory use or as a flat plate module for installation in original equipment, this Model RS450 provides either two 300-400-volt outputs (one positive and one negative), or a single 600-800-volt output. These ranges are available at currents up to 50 ma. Both supplies track each other throughout their ranges; a single voltage adjustment control is rotated on top of the chassis. Bench type sells for $135.50.—Trans Electronics, Inc., Canoga Park, Calif.

Circle No. 319 on reply card

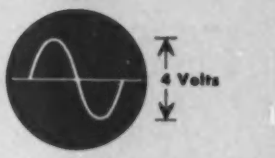
from Honeywell... ANOTHER DIAMOND JUBILEE PRODUCT

WHEN YOU HAVE
extraneous common mode signals



AND WANT TO MEASURE
0.1 to 100 millivolts full scale

AND THEN AMPLIFY



CHOOSE THE NEW HONEYWELL D-C AMPLIFIER

AccuData II

wide-band differential all-transistor D-C Amplifier for strain gages and thermocouples

- **Full Scale Input:** Unbalanced: ±100 μv to ±100 mv Differential: ±3 mv to ±100 mv Open Loop: Below drift level
- **Full Scale Output:** ±2v at 50 ma, dc to 10 kc
- **Frequency Response:** to 20 kc
- **Output Impedance:** Less than 0.5 ohm at dc on all ranges
- **Input Impedance:** Unbalanced 3 to 100 mv ranges; greater than 20 megohms in parallel with 350 micromicrofarads. Differential: Greater than ± 2 megohms
- **Equivalent D-C Input Drift:** Less than 2 μv/10°F ambient temp change on 0.1 to 30 mv input ranges
- **Equivalent Input Noise:** 4μv peak-to-peak on 100 μv to 300 μv range (0-10 cps). 8μv rms on 10 to 30 mv ranges (0 to 100 kc)
- **Common Mode Rejection:** 200,000 at 60 cps on 3 to 30mv ranges

The new Honeywell AccuData II is a completely transistorized D-C Amplifier designed for use in high accuracy data handling systems as a wide-band pre-amplifier for strain gages and thermocouples. Its output can be fed to electronic or electromechanical analog-to-digital converters and simultaneously recorded on galvanometer oscillographs or magnetic tape. Either differential or single-ended input modes can be selected by an eleven position range switch. This switch changes the gain in three-to-one steps. Intermediate gains with high resolution are provided by a ten-turn potentiometer Write for AccuData II Bulletin to Minneapolis-Honeywell, Dept. 84, Boston Division, 40 Life Street, Boston 35, Mass.

Honeywell

First in Control

SINCE 1885

IF relays cause you as much trouble as they do us, you will undoubtedly welcome information on how to get rid of them. Probably the most fashionable way to do the switching is to use transistors, and as a public service Sigma hereby offers some application data toward this end. The Search for Truth must go on.

Right off the bat, it must be conceded that transistors have the edge in several important physical and dynamic respects. Relays are certainly bigger, heavier and slower, and their useful life is nowhere near infinite—primarily because they all have such old-fashioned things as moving parts. Nor are relays immune to unlimited shock and vibration (the best we've been able to do on a subminiature type, and keep it operating within spec, is 30 g's to 5000 cycles).

There are a few things relays *are* good for, however, even though "Relayized" may never sell a single product. For instance: signal circuits can be isolated from load circuits . . . signal and load can be AC or DC, in any combination . . . circuits with high voltage to ground present no particular problems, and relatively high voltage loads can be handled . . . inductive loads can be switched "off" when they're supposed to be off. On "sliding" or slowly varying signals, the right relay will also provide clean, positive switching and it won't fry if the circuit develops a mild defect. It is true, if not grammatical, to say that a relay is many orders more "off" and several orders more "on" than those other things.

The fact that relay contacts more closely approximate the ideal switch—no ohms one way and infinite ohms the other way—also means something when dry circuit switching is your problem. With loads in the order of 0.1 microwatt, a properly designed relay can provide dependable switching.

Further, if 3-position, polar, center-stable switching (Sigma "Form X") is needed, a single relay will do the job. And if the requirement calls for having the switch "remember" and stay in the last switched position, a polarized, magnetic latching relay (our "Form Z") will do just that without stand-by power.

There are also such considerations as *cost* (where the switching is of the pinball machine variety), *stability* as a function of temperature, and *amplification* (10,000:1 load to signal ratio), that lean in favor of relays. But the main ones are those mentioned earlier—which we're banking on to keep us from going bankrupt this year. In the meantime, we're looking around for diversification possibilities—something in a good solid state, perhaps.

HOW TO AVOID RELAYS*

*or, Ten Easy Steps to Utopia.

SIGMA INSTRUMENTS, INC.
69 Pearl St., So. Braintree 85, Mass.
An Affiliate of The Fisher-Pierce Co. (since 1939)

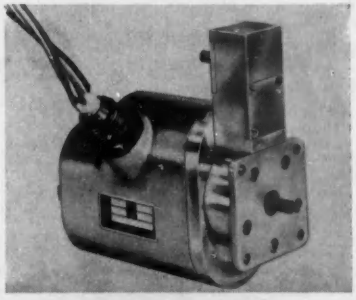
NEW PRODUCTS

PLUS . . .

(320) A unique synchronous-switching **static inverter,** under development by the **Tapco Group of Thompson Ramo Wooldridge. Inc.,** Canoga Park, Calif., converts 24-28 vdc to a three-phase, 400-cycle, stepped-wave, 110-volt alternating current. . . . (321) A militarized **dc power supply,** available from **Perkin Engineering Corp.,** El Segundo, Calif., supplies 26.5 volts at 100 amps for ground radar applications. . . . (322) **Power Sources, Inc.,** Burlington, Mass., recently unveiled two new lines of **transistor-regulated power supplies**—one for low voltage and the other for high voltage applications.

Circle Nos. 320, 321, or 322, on reply card

ACTUATORS & FINAL CONTROL ELEMENTS



LEAK-FREE AT 20 PSI

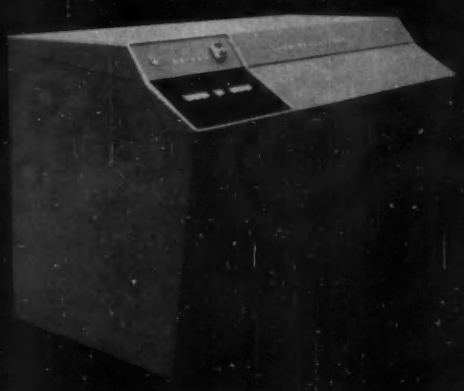
Originally designed to position a ball valve while fully submerged in gasoline, this compact motor driven actuator develops 100 lb-in. of starting torque and provides a nominal running torque of 25 lb-in. Its cast aluminum case will withstand 20 psi without leaking. A Geneva movement insures an accurate and repeatable 90-deg shaft rotation. Unit weighs 2.6 lb and is roughly 3 in. square by 5 in. long.—Globe Industries, Inc., Dayton, Ohio.

Circle No. 323 on reply card

FITS VALVE STEM

The SM-11 electric rotary valve actuator measures 4½ in. in diameter by 5 in. long, develops torque of 125 lb-

RW-300



the most field-reliable computer control system

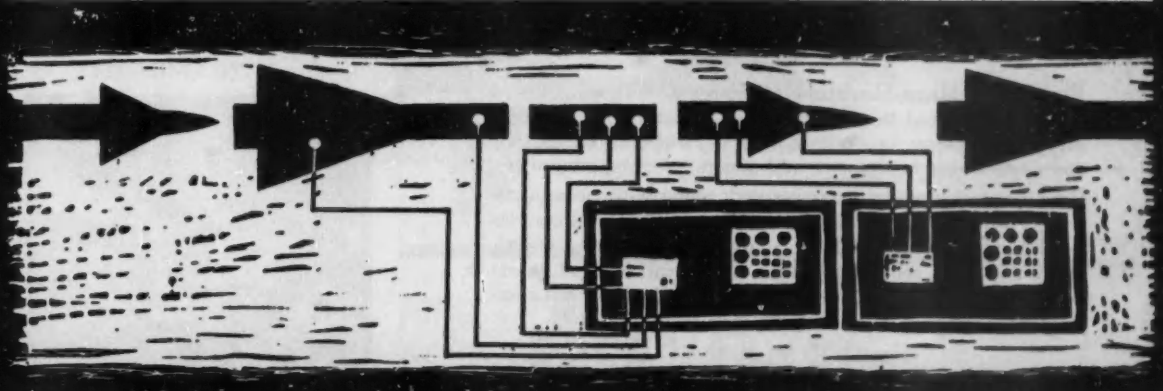
FOR AUTOMATIC CONTROL OF PRODUCTION TESTING

Through automatic testing of complex components, assemblies, and complete systems, the RW-300 Digital Control Computer can significantly reduce test time, improve quality control, and lower manufacturing costs.

As the central unit of a versatile automatic testing system, the computer releases highly trained technical personnel from repetitive testing duties and the detailed design of special testing equipment. Computer control eliminates human error and provides test routines that are exactly reproduced time after time. Unlike special test equipment that must be redesigned to meet new requirements, the RW-300 system permits test routines to be modified or completely changed merely by reprogramming the computer.

Leaders in missile, electronics, and other industries are now introducing the RW-300 into production testing. They take confidence in the fact that it is the only digital control computer already proved out in more than a dozen on-line industrial applications.

For further information, call or write Mr. Raymond E. Jacobson, Director of Marketing, Dept. 1078.



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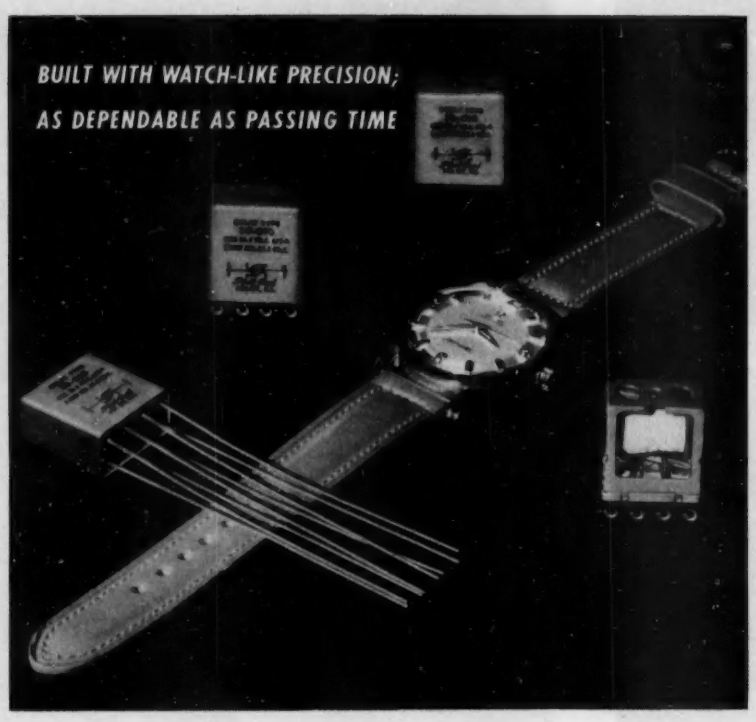

New Phillips Micro-Miniature Relays Are Rugged, Versatile In Application, Highly Reliable

Phillips new Micro-Miniature Relays are carefully engineered and manufactured to assure the very maximum in reliability and performance for control systems, airborne computers, communications equipment, and general electronic circuitry. Flexibility of application is assured, along with prompt delivery, because of the wide selection of standard Phillips styles available. Insist on Phillips compact, hermetically sealed, micro-miniature relays when your designs call for quality and dependability. Your nearest Phillips Sales Engineer has complete data ready now to fill your inquiry immediately.

TYPICAL ENGINEERING DATA:

SIZE: Height, .875 Max.	RATING: 3 Amps. 26.5 Volts dc
Width, .800	Also Low Level
Thickness, .387	circuit applications
13 STANDARD STYLES	12 STANDARD COIL RATINGS

For Complete Details, Write for Phillip s Micro-Miniature Type 30 Brochure.

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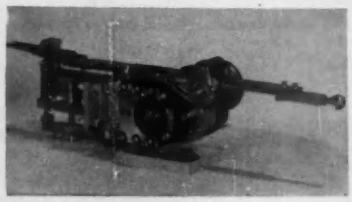
186 CIRCLE 186 ON READER SERVICE CARD

NEW PRODUCTS

in., and provides full scale control in as little as 1 sec with remote control accuracy of one part in 1,000. Remote manuals for automatic controls may be used. Automatic control is usually provided by a transistorized amplifier whose output drives the control phase of the actuator motor.—Jordan Controls, Inc., Milwaukee, Wis.

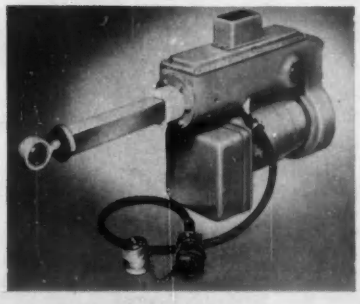
Circle No. 324 on reply card



TAKES HIGH AMBIENT

Developed for use in a 1,200-deg F direct ram air system, this rugged, pneumatic servoactuator has undergone a severe 42-hr endurance test where temperatures ranged up to 1,600 deg F. Its prime mover consists of an opposed pair of nutating disc air motors with a rack and pinion drive. Fast response combined with advanced pneumatic servovalve and stabilization techniques make it suitable for use in aircraft, missile, and nuclear control systems.—The Marquardt Corp., Van Nuys, Calif.

Circle No. 325 on reply card



BUILT FOR INDUSTRY

Built with the same precision as the company's aircraft and missile actuators, this Model 499B electrically driven linear actuator is designed for industrial applications requiring open-loop positioning. Its 115-volt, single phase, 60-cycle motor develops 0.14 hp at 5,000 rpm and, through suitable reduction, furnishes sufficient power to move up to ¾ ton. Unit also contains a brake to mimimize overcoast

and will hold up to 1½ tons. Stroke is continuously adjustable from 4.25 to 5.25 in. Only connection required is a 115-volt line.—Lear, Inc., Grand Rapids, Mich.

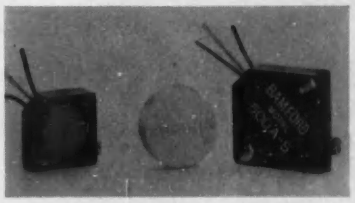
Circle No. 326 on reply card

PLUS . . .

(327) The **Joyce-Cridland Co.**, Dayton, Ohio, offers a new line of custom-fabricated single-acting **hydraulic cylinders** with diameters from 4 to 18 in. and capacities up to 75,000 lb. . . . (328) A combination **high-pressure relief, pressure reducer, and check valve**, available from **Vinson Engineering & Sales Corp.**, Van Nuys, Calif., operates at pressures up to 4,000 psi. . . . (329) **Milo Manufacturing Co.**, Elizabeth, N. J. has announced the development of a new **electromagnetic valve** for remote control of low pressure liquids and gases.

Circle Nos. 327, 328, or 329 on reply card

COMPONENT PARTS



TINY TRIMMING POTS

Featuring a square design for easier stacking, these new subminiature wire wound trimming potentiometers are available with either 1- or 2-watt power ratings. Models in the 1-watt 375 Series weigh less than 1 gram, have resistance ranges from 10 to 50K ohms, and measure 0.375 in. square by 0.175 in. thick. The 2-watt 500 Series models are ½ in. square by 0.175 in., weigh less than 2 grams, and are available with ranges up to 100K.—Bamford Corp., Los Angeles, Calif.

Circle No. 330 on reply card

WORLD'S FASTEST

A new "Avalanche Mode" silicon transistor, designated 2N1468, is said to be capable of performing switching functions in as little as 1.5 x 10^{-9} sec. Anticipated applications include computers, sampling oscilloscopes, klystron

liquid column accuracy beyond liquid column range

A combination of Ni-Span-C* Bourdon tubes, a special ratio linkage and custom calibration set these W&T gauges apart. Use of corrosion-resistant Ni-Span-C eliminates temperature compensation, makes the gauge usable in a wide variety of applications. Dual Bourdon tube mechanism provides high accuracy measurements of absolute or differential pressures without applying any system pressure to the gauge case. The special ratio linkage provides low friction, practically no hysteresis. Custom calibration means rapid, accurate readout, as in all W&T precision pressure instruments.

W&T Bourdon tube gauges have:

Max. Range—0-500 p.s.i.; absolute, gauge or differential
Min. Range—0-30 p.s.i.; absolute, gauge or differential
Sensitivity—1:8000
Accuracy—0.2% of full scale range
Hysteresis—negligible
Temperature effect—0.075% of range/10°C

For full information and technical data address Dept. A-122.38

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NEW PRODUCTS

pulsing equipment, and other equipment in which the switching capacity of transistors limits both speed and efficiency. Designed to operate at temperatures up to 125 deg C, the 2N1468 features an average turn-on-time of 4 microsec switching 40 watts peak power with an average power dissipation of only 250 mw. Emitter cutoff current varies from an average of 0.01 to maximum of 1.0 microamp. Collector-to-emitter and avalanche voltages both vary from a minimum of 40 volts to an average of 70 volts. —Raytheon Co., Needham Heights, Mass.

Circle No. 331 on reply card

DUAL FLIP-FLOP

Shown is a transistorized dual flip-flop that can be used with circuits having noise levels as high as 2.5 volts. Designated Model S-84001-PD, the plug-in unit provides for reset, set, and trigger (or binary) operation, as well as manual reset, in each flip-flop. Saturated circuitry insures maximum reliability. Pulse repetition rates to 150 kcps with a 4 microsec resolution are standard.—Plug-In Instruments, Inc., Nashville, Tenn.

Circle No. 332 on reply card

PLUS . . .

(333) Using RCA's newly developed Nuvistor vacuum tubes, **Mini-Rad, Inc.**, North Hollywood, Calif., has produced a new series of subminiaturized **blocking oscillators** for both military and industrial applications. . . . (334) **Texas Instruments Inc.**, Dallas, Tex., is now producing the TI-110 series of PNPN diffused **silicon controlled rectifiers**, rated at 1 amp from 50 to 400 volts.

Circle Nos. 333 or 334 on reply card

CIRCLE 189 ON READER SERVICE CARD→

SIMPLE • VERSATILE • UNIQUE

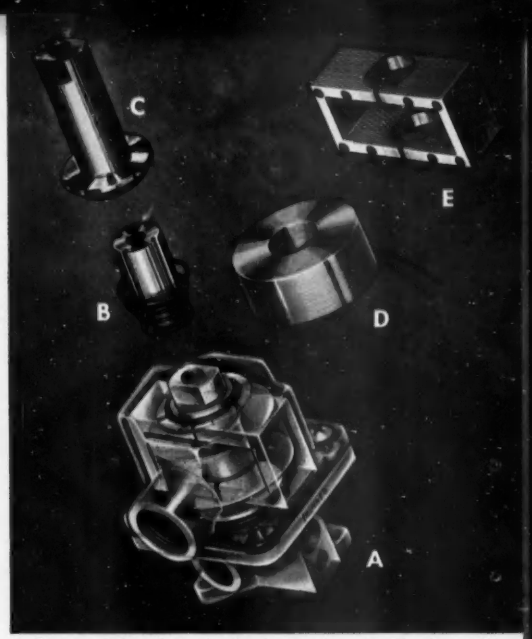
New **SKINNER** 3-way Solenoid Valves

All Skinner Solenoid Valves are...

SIMPLE— Only two moving parts in direct acting valves. Stainless steel internal parts resist corrosion. Soft synthetic inserts provide bubbletight sealing. Most types available in explosion-proof construction.

VERSATILE— Literally thousands of variations are possible—mounting, flow control and porting . . . electrical options in coils, voltages and frequencies . . . types of media, operating temperatures, etc.

UNIQUE— Skinner valve seat does not cut inserts, assures bubbletight sealing and long life. Skinner valve sleeve assembly is precision welded to provide over 5,000 PSI burst strength. Skinner standard valve designs are readily modified for custom applications. From first step in manufacturing to delivery, Skinner quality control and 100 per cent testing builds valves Skinner guarantees for long, trouble-free life.



A—Transparent view of normally closed valve with main orifice shown solid
B—Plunger and spring C—Sleeve D—Coil E—Yoke

SKINNER three-way solenoid valves solve your control system problems

Whatever your problem in controls . . . in machine tool automation, automatic clutching or braking, packaging, instrumentation, laundry equipment, air conditioning, or in any of thousands of applications involving air and hydraulic cylinders or pressurized mechanisms . . . Skinner has the answers.

Skinner design leadership and quality manufacture of solenoid valves has been proved by universally successful use. And as control problems become more complex, Skinner keeps pace with new designs, new valves, and continued top quality production.

The new A series shown above, the new L series, the V5 and V10 series complete the line of Skinner 3-way solenoid valves. Your selection is unlimited.

	V5 Series	V10 Series	A Series	L Series
Orifice sizes	1/32" to 1/4"	3/32"	3/32", 1/8", 1/32"	3/16", 1/8", 3/4"
Pressure Ratings	Up to 200 PSI	1000 PSI	Up to 250 PSI	5 to 150 PSI
Types	Normally open, normally closed, directional control, multi-purpose	Normally open, normally closed, directional control, multi-purpose	Normally open, normally closed, directional control, multi-purpose	Normally open, normally closed, directional control
Construction	Stainless steel body Stainless steel internal parts	Stainless steel body Stainless steel internal parts	Zinc die-cast body Stainless steel internal parts	Forged naval brass body Stainless steel and brass internal parts
Body Pipe Connector	1/8 and 1/4 NPT	1/8 NPT	1/4 NPTF	3/8", 1/2", 3/4" NPTF

When you specify solenoid valves, specify Skinner. **Skinner solenoid valves are distributed nationally.**

For complete information, contact a Skinner Representative listed in the Yellow Pages or write us at the address below.

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1	11	21	31	41	51	61	71	81	91	101	111	121	131	141	151	161	171	181	191
2	12	22	32	42	52	62	72	82	92	102	112	122	132	142	152	162	172	182	192
3	13	23	33	43	53	63	73	83	93	103	113	123	133	143	153	163	173	183	193
4	14	24	34	44	54	64	74	84	94	104	114	124	134	144	154	164	174	184	194
5	15	25	35	45	55	65	75	85	95	105	115	125	135	145	155	165	175	185	195
6	16	26	36	46	56	66	76	86	96	106	116	126	136	146	156	166	176	186	196
7	17	27	37	47	57	67	77	87	97	107	117	127	137	147	157	167	177	187	197
8	18	28	38	48	58	68	78	88	98	108	118	128	138	148	158	168	178	188	198
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201	211	221	231	241	251	261	271	281	291	301	311	321	331	341	351	361	371	381	391
202	212	222	232	242	252	262	272	282	292	302	312	322	332	342	352	362	372	382	392
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205	215	225	235	245	255	265	275	285	295	305	315	325	335	345	355	365	375	385	395
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207	217	227	237	247	257	267	277	287	297	307	317	327	337	347	357	367	377	387	397
208	218	228	238	248	258	268	278	288	298	308	318	328	338	348	358	368	378	388	398
209	219	229	239	249	259	269	279	289	299	309	319	329	339	349	359	369	379	389	399

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2	12	22	32	42	52	62	72	82	92	102	112	122	132	142	152	162	172	182	192
3	13	23	33	43	53	63	73	83	93	103	113	123	133	143	153	163	173	183	193
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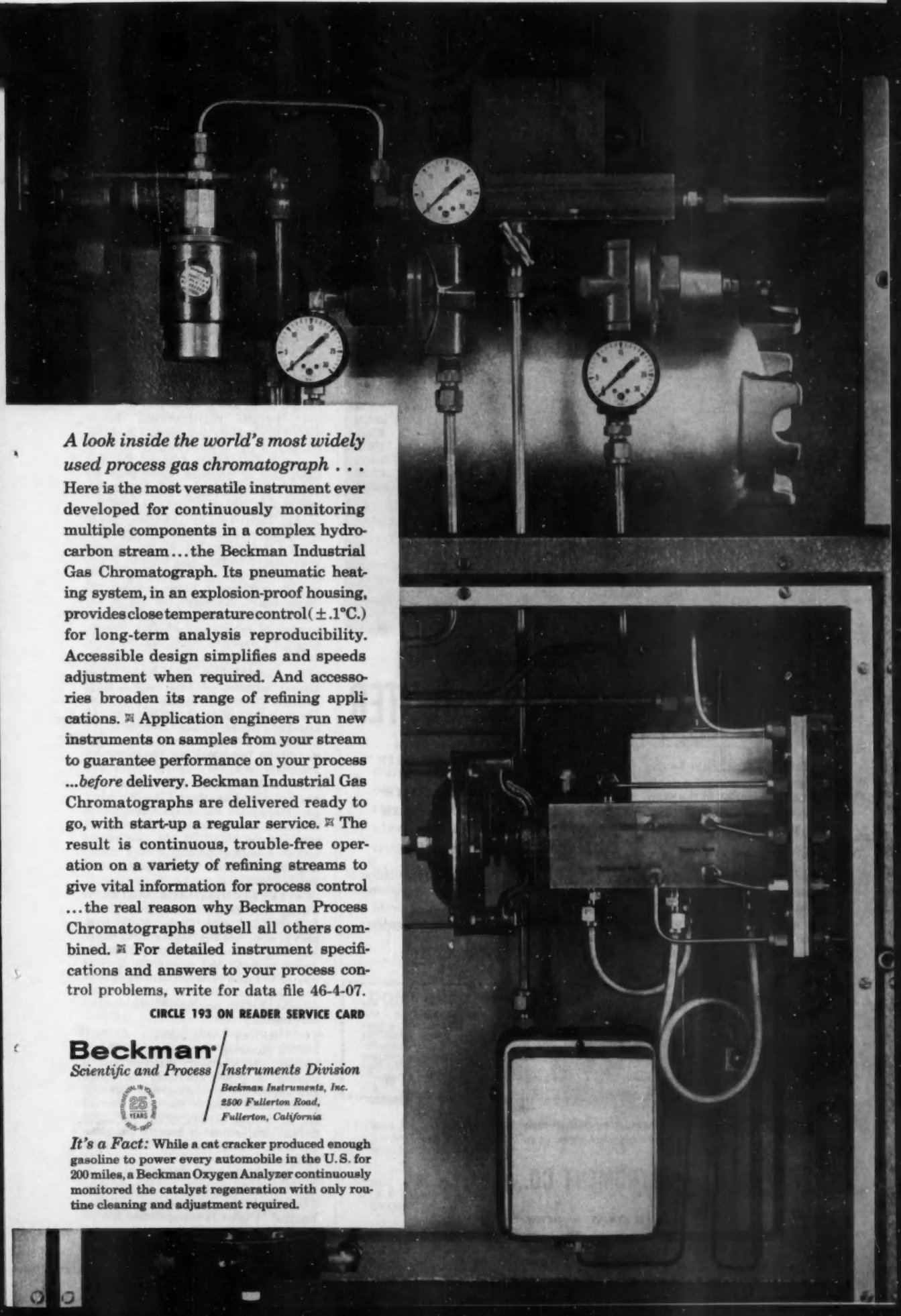

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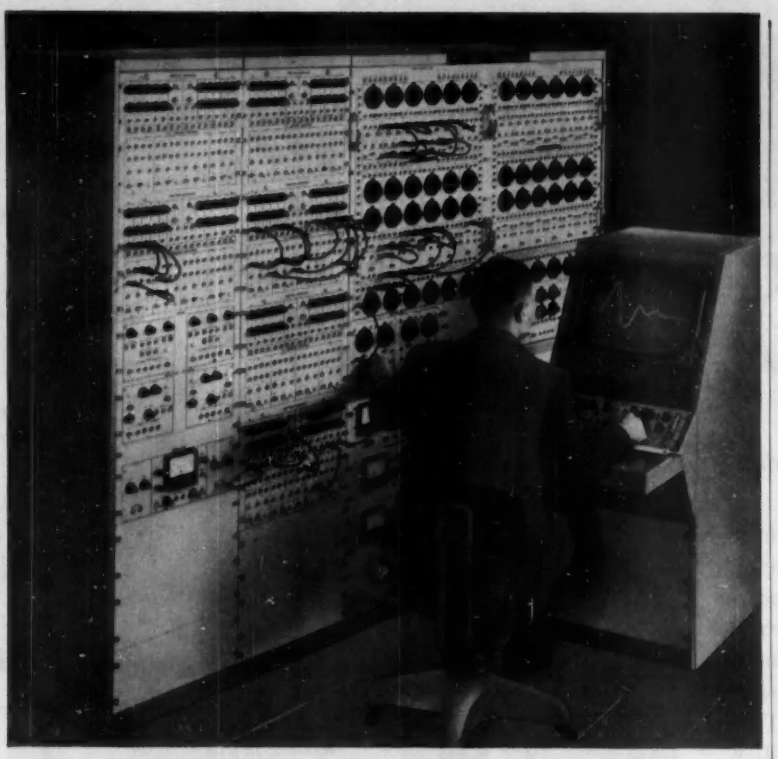

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BULLETINS AND CATALOGS

(350) SERVO MOTOR TEST. Helipot Div., Beckman Instruments, Inc. Test report T-249, 14 pp. Comprehensive report describes electrical and mechanical characteristics of Beckman's Size 8 servomotors under various environmental conditions. Covers the purpose and nature of the tests as well as the apparatus used. Procedures are listed in detail; results and conclusions are fully tabulated.

(351) FOR AUTOMATIC CHECKOUT Equipment Div., Epsco, Inc. Bulletin, 4 pp. Contains photographs and brief descriptions of four Mil-spec instruments for automatic checkout systems: a rms to dc converter, a voltage to digital converter, a timer-counter, and a digital printer.

(352) FLOW INDICATORS. Instrument Div., Schutte & Koerting Co. Bulletin M-1, 4 pp. Well illustrated, this condensed bulletin briefly describes the division's line of precision instruments for measuring, indicating, recording, and controlling flow rate of all types of fluids.

(353) TOGGLE SWITCHES. Micro Switch Div., Minneapolis-Honeywell Regulator Co. Catalog 73d, 32 pp. Includes dimension drawings, specification tables, and photographs covering a wide variety of high performance toggle switches and toggle switch assemblies for use in airborne, mobile, marine, electronic, and commercial applications. Military versions, tested and approved under MIL-S-3950A, are also presented.

(354) COMPUTER PROGRAMMING. Donner Scientific Co. Tech Note 2, 4 pp. Feature article in this second issue of Donner's Tech Notes in entitled "How To Use And Program Analog Computers". To illustrate techniques involved, the author investigates two problems: the suspended pendulum and the inverted pendulum.

(355) INDUSTRIAL pH METER. Milton Roy Co. Data sheet EIL 28 AM, 2 pp. Emphasizes the design features of a miniature, nonindicating industrial pH amplifier, the Model 28 AM. Illustrations include a photograph and a basic circuit diagram. Also contains a complete list of specifications.

(356) LEVEL-INDICATOR AND CONTROL. The Euclid Electric & Mfg. Co. Bulletin E-200, 4 pp. Deals with the company's new Sen-Tek light-sensing level-indicating system, a complete package designed to detect and control the level of opaque and solid materials, either coarse or fine. Illustrates one typical application and provides detailed descriptions of individual components.

(357) RELAY MAGNETIC AMPLIFIERS. Acromag, Inc. Bulletin 70, 6 pp. Features 10 schematic diagrams and a number of graphs describing the design and application of single-ended magnetic preamplifiers. Some of the topics covered are: ac doubler circuits, dc double bridge circuits, snap-action or bistable characteristics, and a magnetic amplifier-thermistor temperature control system.

(358) JET ENGINE TESTING. Berkeley Div., Beckman Instruments, Inc. Data File 114, 12 pp., plus product bulletins. Entitled "Digital Instrumentation For Jet

Engine Testing", the data file describes typical engine test systems, equipment required, and techniques used for monitoring fuel flow, water flow, and compressor speeds. Product bulletins cover various types of flow transducers, tachometer pickups, electronic counters, data converters, indicators, and recorders.

(359) CONVERTER LINE. Adage, Inc. Catalog, 6 pp. Presents engineering data and performance specifications covering eight basic types of voltage to digital converters for a variety of data processing applications.

(360) PRESSURE SWITCHES. Newark Controls Co. Four technical data sheets, 2 pages each. Individual sheets describe and illustrate two absolute air pressure switches and two gas density switches designed for use as control and warning devices in either sealed or open pressure systems. Typical applications, dimension drawings, and specifications are included for each switch type.

(361) SYSTEM CONTROL PANELS. The Fuller Co. Bulletin G-9, 12 pp. Illustrates four basic types of control panels for a wide variety of automatic materials handling system. These include the "walk-in" master control panel, the floor-mounted panel, wall-mounted panel, and explosion-proof panel. Center fold carries schematics of systems used to control unloading, reclaiming, and processing of materials in a brewery and to provide one-man operation of a cement kiln.

(362) COMPLETE BREAKER LINE. I-T-E Circuit Breaker Co. 1960 Speedfax catalog, 60 pp. Designed for fast reference, this comprehensive catalog contains three main sections providing extensive information on 1) molded case circuit breakers, 2) individually-included low voltage power circuit breakers, and 3) special engineered products. Selection charts list available types, ratings, and accessories.

(363) DATA GATHERING. Friden, Inc. Bulletin SP-8665, 16 pp. Outlines the function, application, and advantages of Friden's Collectadata system of code-rating and code-punching units designed to facilitate the collection of data at a central processing point.

(364) METERING PUMPS. Process Equipment Div., Lapp Insulator Co., Inc. Catalog 59, 28 pp. Opens with a brief description of the company's Pulsafeeder metering pumps and a few pages on their operation and construction details. Specific designs for a variety of widely different process applications are then described. Special sections cover autopneumatic and electronic types of controls.

(365) MINIATURE ACCELEROMETERS. Columbia Research Labs., Inc. Bulletin, 2 pp. Lists complete electrical and physical specifications on the Models 200 and 201 miniature true compression accelerometers. Illustrations include dimension drawings, a photograph, and typical plots of both shock response and frequency response.

(366) CAPACITOR CHARACTERISTICS. Sprague Electric Co. Engineering bulletin 2110A, 22 pp. Incorporates a recent reduction in a number of permissible life-test failures for Vitamin Q subminiature metal-clad capacitors. Other changes include addition of data on ter-

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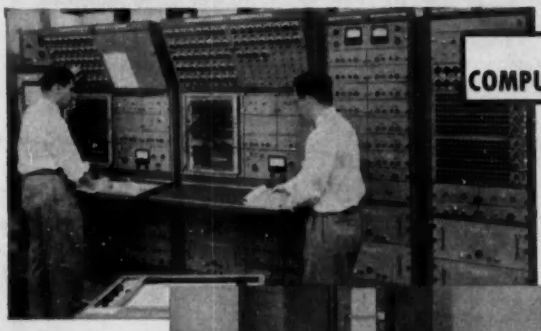

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minal altitude limitations as well as a revised characteristic curve for stabilized-wax capacitors to show both 60- and 1000-cycle characteristics.

(367) LATCHING RELAY. Babcock Relays, Inc. Technical bulletin, 2 pp. Describes the BR-7A latching relay, a recent addition to the company's line of Mil-spec crystal case relays. Dimension drawings cover a variety of mounting types and terminal styles. Tables list standard coil resistances and operating characteristics.

(368) DC POWER SUPPLIES. Dressen-Barnes Corp. Catalog, 16 pp. Provides complete data on every dc power supply in the company's standard line. A handy selection chart permits a user to select output requirements and turn immediately to an appropriate specification table.

(369) INDUSTRIAL RECORDER. General Electric Co. Bulletin GEZ-2969, 4 pp. Describes features, applications, measurable parameters, and specifications for GE's newly announced line of circular chart single- and double-pen recorders. Bulletin also contains a number of dimension drawings and a partial list of available charts and scales.

(370) MERCURY SWITCH CONTROLS. The Mercoid Corp. Catalog 860, 56 pp. Complete with prices effective as of last December, this 1960 catalog describes a variety of mercury switch equipped controls for single-stage pressure, two-stage pressure, differential pressure, single- and two-stage temperature, liquid level, and mechanical motion. Transformer-relays and a complete line of hermetically sealed mercury switches are also included. Products are cross indexed by type number and applications.

(371) LARGE SCALE X-Y PLOTTER. Houston Instrument Corp. Bulletin 794-1, 2 pp. Offers a complete description of a new large scale X-Y recorder designed to handle the output of differential transformers and other ac transducers. Functional block diagram illustrates a typical application.

(372) TIME SEQUENCER. Magnetic Amplifiers, Inc. Bulletin S-1023, 4 pp. Features a functional description of the Model MA 6011 static time sequencer, a self-contained programmer that provides control/power signals for automatically performing test operations in a predetermined sequence. A table of typical time functions is included.

(373) SELECTORS AND STEPPING MOTORS. G. H. Leland, Inc. Bulletin A-4259, 8 pp. Serves as an application guide to Ledex rotary solenoids, selectors, and Syncramental stepping motors. Illustrated with line drawings, charts, photos, and circuit diagrams, bulletin contains specific electronic, mechanical, and environmental performance data on more than 250 different products.

(374) AUTOMATIC WAVE ANALYZERS. Minneapolis-Honeywell Regulator Co. Bulletin DB 9050a, 16 pp. Begins with a few brief comments on the what and how of spectral analyzers and then goes on to describe in detail the design and operation of Honeywell's automatic wave analyzer systems. Closes

with two complete pages of specifications and performance curves.

(375) THERMOCOUPLE ADAPTER. Thermo Electric Co., Inc. Bulletin 2A, 2 pp. Describes a new spring-loaded, thermocouple adapter which converts ⅛- or 1/16-in. Ceramo or other metal-sheathed thermocouple to a spring-loaded, bayonet-lock type with proper immersion lengths.

(376) DIGITAL PROCESS CONTROL. Dynapar Corp. Application data book, 24 pp. Describes a number of typical process control applications in which the company's line of transistorized digital preset counters, process controllers, Rotopulsers, and other sensing devices have been used to provide precise numerical readout and initiate automatic control.

(377) AUTOMATIC DATA LOGGERS. Hanson, Gorrill-Brian, Inc. Brochure, 12 pp. Illustrates H-G-B's diversified Data-Master line of data loggers. Describes the main features of various size units with capacities ranging from 50 points on up.

(378) BREADBOARD COMPONENTS. PIC Design Corp. Technical booklet 4, 24 pp. First 19 pages contain a number or useful design hints and recommendations for instrument engineers concerned with mechanical breadboarding techniques. Balance of the booklet consists of typical pages taken from PIC's master catalog.

(379) ELECTROHYDRAULIC CONTROL. Moog Servocontrols, Inc. Bul'etin 110, 20 pp. Entitled "A Guide to Industrial Electrohydraulic Servo Components and Systems", this bulletin is designed to provide engineers with a current summary of the basic principles and potential applications of electrohydraulic servos. Features extensive typical case histories.

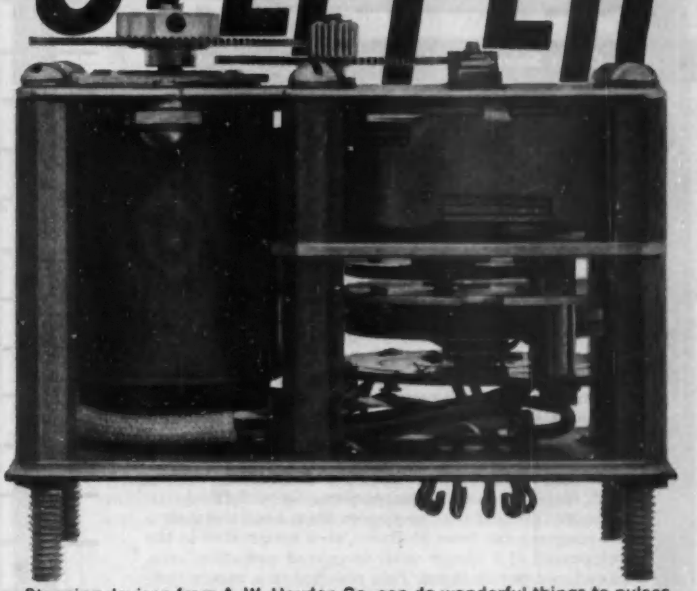
(380) PUMPS AND CONTROLS. Denison Engineering Div., American Brake Shoe Co. Bulletin 220, 72 pp. Comprehensive catalog contains full design details and operating characteristics on the company's complete line of hydraulic pumps, fluid motors, and valves. JIC symbols adjacent to each product discussion simplify preparation of plan drawings. Three-color sectional drawings illustrate operation and special design features.

(381) ROTARY LIMIT SWITCH. Gemco Electric Co. Bulletin 254, 4 pp. Describes the design and operating features of Gemco's lightweight explosion-proof rotary limit switches. Drawings illustrate just a few of their many applications. Table lists catalog numbers along with available gear ratios.

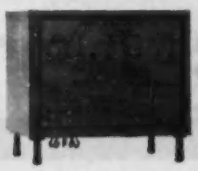
(382) GAS SAMPLING SYSTEMS. The Hays Corp. Publication 59-B651, 8 pp. Provides complete information on the Hays Series 651 gas sampling systems. Offers a step-by-step procedure for selecting components and also lists typical packaged systems for specific applications.

(383) DESIGN REPORT. Servo Corp. of America. Technical Report, 6 pp. Explains application of the Servolab servosystem simulator to the design of a wide variety of control systems for industrial process controls, flight instrumentation systems, guided missiles, ground support systems, nuclear reactor controls, etc. Photos and schematic diagrams illustrate versatility of these electronic and electromechanical assemblies.

FANCY STEPPER



Stepping devices from A. W. Haydon Co. can do wonderful things to pulses ...with pulses...and for pulses. For instance, one precision gated stepping switch acts as a pulse divider for a random or variable pulse source—or as a frequency divider if the pulse source is constant. Another works in conjunction with pulses, supplying single or multiple switch closures with an accuracy virtually equal to that of the pulse source itself. Still a third will count a predetermined number of pulses, rotate a stepper switch, return the counter to 000, and cut off the pulse source. ■ The remote positioning device illustrated is but one of A. W. Haydon Company's fancy steppers. Here a precision gated stepper switch has been coupled to a synchro transformer. Similarly, precise angular positioning of rotary components such as potentiometers, dials and indicators can be controlled. Based only on the number of pulses received (not incremental changes in voltage or phase angle), it will hold a set position whether power is on or off, and will home the synchro to the zero reference on demand—ready to accept another setting. ■ All A. W. Haydon Co. stepper motors are all-electric—no ratchets, linkage, contacts or other mechanical crutches are used. Their power consumption is low, accuracy is extremely high. ■ Send for technical brochure SP9-1 and find out more about pulse driven steppers and their application.



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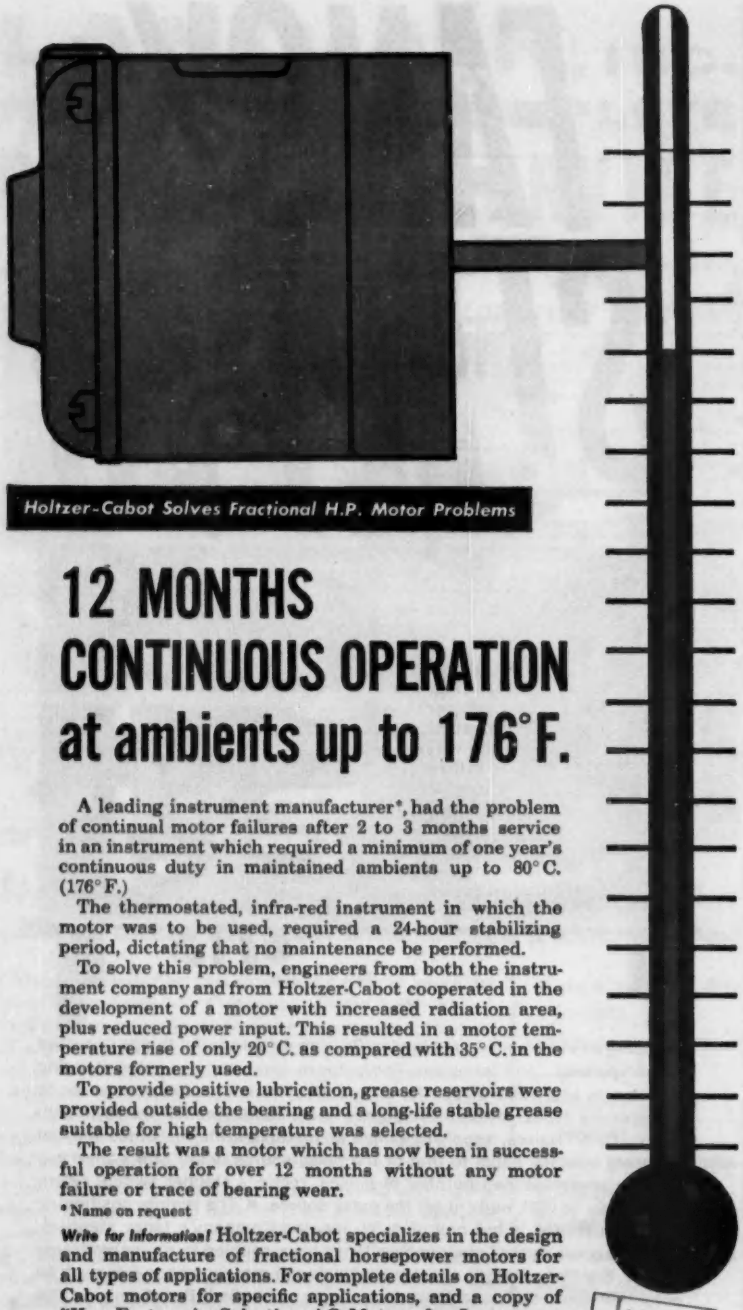

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To solve this problem, engineers from both the instrument company and from Holtzer-Cabot cooperated in the development of a motor with increased radiation area, plus reduced power input. This resulted in a motor temperature rise of only 20° C. as compared with 35° C. in the motors formerly used.

To provide positive lubrication, grease reservoirs were provided outside the bearing and a long-life stable grease suitable for high temperature was selected.

The result was a motor which has now been in successful operation for over 12 months without any motor failure or trace of bearing wear.

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Write for Information! Holtzer-Cabot specializes in the design and manufacture of fractional horsepower motors for all types of applications. For complete details on Holtzer-Cabot motors for specific applications, and a copy of "Key Factors in Selecting AC Motors for Instrument Service" write direct or use Readers Service Card.

HOLTZER-CABOT

MOTOR DIVISION

National Pneumatic Co., Inc., Boston 19, Mass.

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WHAT'S NEW

(Continued from page 49)

ceived Conoflow's "equal treatment", and a quotation was rushed out. But at the same time, Fusfeld was alerted in Holland and he made a personal call to follow up the quotation. Continued face-to-face selling by Fusfeld got the business. As a result, the Conoflow nameplate is proudly displayed in Africa on the company's first shipment of jungle-proof valves.

Russians Add French Show To Germany's, UK's

—LONDON

Most recent European country to accept a Russian invitation to exhibit instrument wares in Moscow's Polytechnic Museum is France, which has announced that a 10-day display will be held there this month. The French thereby become the third country to reveal similar plans.

Last November Germany held an instrument exhibit in the USSR, and, as reported previously in CtE (Jan. '60, p. 57), the British Scientific Instrument Manufacturers Association has a show scheduled for June 16-26.

In each case it was the Russians who requested the trade show, but consistently they have been careful not to specify any particular area of interest to be emphasized in the exhibitions. SIMA, for instance, is planning a wide scope event, omitting equipments that are embargoed for export to Communist-bloc countries.

The feeling in London is that the Russians are using these shows to keep themselves up-to-date on what each country can do. Being the unpredictable buyers for a potentially huge market (if the wind blows in the right direction) allows them to call the tune and get everyone to send a show to Moscow.

—Derek Barlow

New Company to Train Commuter Programmers

Electronic Computer Services, a new company formed in Chicago by Gordon D. Shoholm, will be the first firm in the country to train computer programmers and also to perform computer consultation and contract computer work.

ECS will set up computer service centers (first in Chicago in 1961) where it will do computing and train customers' personnel. As a service for banks too small to own a computer, ECS hopes to get a GE 210, the machine used in the Bank of America ERMA system.

Lease a Control System—
—Or Anything Else

New developments in equipment leasing now open the door to cheaper procurement of modern equipment by control system users and higher sales by control equipment makers. The latest: keen competition by companies who'll lease just about anything.

Equipment manufacturers have long been leasing their own line of products. For example, far more electronic computers have been rented out than have been sold outright. Car and truck rentals are quite common. Now the push is by leasing outfits which can make available for lease a couple of office machines, an automatic production line, or all the equipment needed to set up a business.

• **Hertz jumps in**—Recently Hertz Corp. announced that it is setting up a Hertz Equipment Leasing Corp. to lease anything. The Chicago company, long a leader in car and truck rentals, will buy and lease whatever equipment a customer wants.

The customer selects the gear from a supplier of his choice at a price the customer works out. Hertz then buys the equipment and signs the lease with the user.

Big drawback: maintenance and repair services will be only those that the manufacturer normally offers with sales of his equipment. Hertz will do no such work. Rates will be about 3.2 percent of the original cost per month for three years. At the end of that time, the lease can be renewed at the customer's option for 5 percent a year.

Hertz is not the originator of the "lease anything" setup, however. U.S. Leasing Corp. of San Francisco is the largest general leasing company in the country, and they've been doing it since 1952. Their leases usually run five years, but others are available.

• **Cash in the hand**—USL says, for $10,000 worth of equipment, the rental fee over five years would be $12,660, but tax credits would reduce the cost to $6,075. Purchasing would cost $4,320 in actual cash after depreciation and tax reductions, so the leasing costs an extra $1,755. But here's the payoff: the equipment user has $9,578 additional cash to work with the first year, $6,803 the next, and so on.

However, USL's leases have the same sore point as Hertz's: no maintenance outside of the manufacturer's usual warranty.

• **Rent-a-factory**—USL will lease a control system only if it's part of some end piece of equipment. They'd write a lease on an automatic can line, for instance, but not on the separate de-

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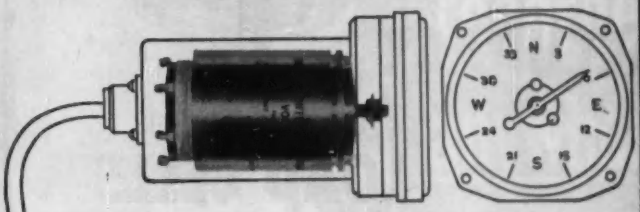
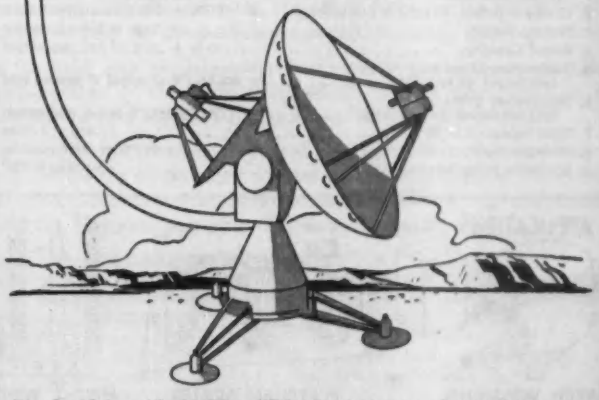
60-CYCLE SYNCHRO INDICATOR



Now available a 23TR6a Synchro Receiver conveniently packaged for immediate installation in ground support equipment consoles or shipboard installations. Your choice of dial presentations which will accurately display the angular or position information received from a remote synchro transmitter. The receiver is ready for front or rear mounting in a 3¼" panel cutout with four .144 holes equally spaced on 3.5 diameter. The receptacle provided on the receiver mates with an AN3106-14S-2S plug. Power requirements are 115 volt, 60 cycle using 5 watts. The receiver is pressure sealed by "O" rings for protection against sand, dust and moisture. The synchro contained in this indicator meets the requirements of MIL-S-20708.



West Coast Sales and Service Office—117 East Providencia Avenue, Burbank, California
Canadian Sales Office—Aviation Electric Limited, 200 Laurentian Blvd., Montreal, Quebec, Canada
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Bendix AVIATION CORPORATION

NEW!

GREATER...

• OUTPUT

• STABILITY

• ACCURACY

• Multi-column

• Smaller size

• Hermetically sealed

Cox and Stevens

LOAD CELLS

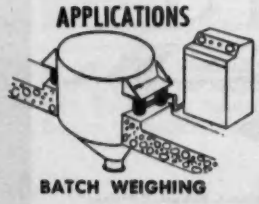
For greater accuracy and stability in all types of weight and force measurement, specify new Cox and Stevens hermetically sealed load cells. Sixteen strain gages in multi-column design provide up to 250% greater output, improved stability and better uniformity between cells. Capacities range from 500 to 200,000 lbs. All cells with 30 feet of special moisture- and chemical-resistant cable in stainless steel jacket.

Cox and Stevens' fifteen years experience in designing and manufacturing load cells, plus dead weight testing facilities which make possible calibration to higher accuracies, assure maximum reliability. Write for technical bulletins.

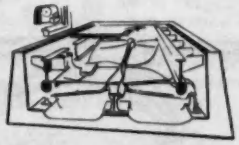
TYPICAL SPECIFICATIONS

1. Recommended Input:	20 volts
2. Change in Output, No Load to Full Load:	1.750 ± .1% millivolts/volt input
3. No Load Output:	± .25% of full load output
4. Output Linearity:	0 to + .20% of full load output
5. Temperature Effect on Cell Output (15 to 115°F):	± .0008%/°F of output at applied load
6. Temperature Effect on No Load Output (15 to 115°F):	± .0013%/°F of full load output
7. Input Impedance at 75°F:	450 ± 1 ohms
8. Allowable Load:	225% of rated capacity
9. Deflection Under Rated Load:	Less than 0.003"

APPLICATIONS



BATCH WEIGHING



PLATFORM SCALES

MISSILE WEIGHING

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53

REVERE CORPORATION OF AMERICA

Wallingford, Connecticut

A SUBSIDIARY OF NEPTUNE METER COMPANY

neptune

vices that might control it.

Biggest lease customers for USL are chemical manufacturers, food processors, the bottling and brewing industry, auto and auto parts makers, machinery builders, and petroleum companies. Electronics manufacturers represent 11 percent of the firm's business; aircraft and aircraft parts makers, another 6 percent.

• **J&L's "no down payment"**—One manufacturer to start a push recently for a program of equipment leasing is Jones & Lamson Machine Co., Springfield, Vt., machine tool builder. As a cure for the claimed $10 billion, obsolete production machinery ill, J & L's plan features no capital outlay, no purchase obligation (or option), and payments at rates claimed to be payable out of "Profitivity", a coined term to describe increased profits from increased production.

Jones & Lamson will lease any equipment they make (products of other manufacturers can be included in a package deal with J & L goods) for a period of five years with first payments due 30 days after delivery, after the machines have started paying off. The rate is $20.50 for each $1,000 of original cost (that's 4.6 percent a year, less than some borrowing rates). After the initial lease, the term can be extended at one-third the prime rate. Normal maker's guarantees are included, nothing more.

• **A tax problem**—Starting in January 1954, Warner & Swasey Co., another big machine tool maker of Cleveland, Ohio, started leasing its equipment. They've run into an interesting tax hassle, though (not involving the customer). The Internal Revenue service claims wording of W & S's leases makes them sales, not leases. IRS has claimed income tax on the full price in the year of the sale, wants W & S to put up the difference. The company is contesting the ruling.

General Electric Co.'s Computer Dept. has also announced a new leasing arrangement. As a first step in an overall rental program for industrial computers, GE will let five-year leases on its $8,600 miniaturized ac network analyzer. Monthly rental through the GE Credit Corp. will be $180 a month. GE's lease of industrial process control computers would be a first, only data processing computers have been rented so far.

Leasing has become a smart way of obtaining equipment. Besides the elimination of capital outlays that are replaced by rental fees equivalent to

loan rates, the leasing costs are income tax deductible as business expense.

Advantage, too, is obsolescence insurance. Antiquated tax rules force purchased equipment to be depreciated over longer terms than is reasonable in a fast-moving technology. Push behind computer leasing is the customer's option of having an out-of-date computer hauled away at the end of a lease and getting a modern one.

Big gain included in the computer company leases is a provision for maker repair and maintenance that hasn't shown up in any of the lease company setups. Users don't want to have to train their own technicians to service complex equipment.

Nevertheless, leasing is growing fast. Nationwide Leasing Co. claims that its leasing of machine tools and other capital equipment will double in 1960. According to Nationwide, leasing by metalworking firms was up 26 percent in 1959 from '58. And another large car rental firm may join Hertz; Avis Rent-a-Car is reportedly studying entering the field.

Northrop Buys Military Div. Of American-Standard

Further evidence of aircraft companies' inclination to turn to electronics, and particularly controls, in diversification efforts (see CtE, Mar. '60, p. 208 for another recent example), is Northrop Corp.'s recent announcement that it has purchased the Military Products Div. of American Radiator & Standard Sanitary Corp.

The Norwood, Mass., (suburban Boston) operation will become the Precision Products Dept. of Northrop's Nortronics Div., Anaheim, Calif. The acquisition will expand Nortronics' electronics capability, boosting the division's sales from $60 million annually to about $75 million.

Nortronics is the electronics arm of Northrop, making guidance systems, test and checkout gear, computing equipment, flight control systems, and related products.

Robertshaw-Fulton Acquires Microsen Business

Agreements were concluded last month for the sale of the electronic process control instrumentation business of Manning, Maxwell & Moore, Inc. to Robertshaw-Fulton Controls Co. of Richmond, Va. Known as the Microsen line, the business is now being moved from its plant at Stratford, Conn., to facilities at Robertshaw's Aeronautical and Instrument Div., Anaheim, Calif.

The Microsen line had been some-

Now you can record test data on-the-spot. In both lab and field you get accuracies equal to or better than big, rack mounted units. Just pick up and move a multi-channel (up to 14) PI tape recorder/reproducer as you would any other item of test equipment.

Instead of 1,000-lb. cabinets, requiring 1000 watts, you're working with recorders 10 times smaller and lighter, using 250 watts or less.

In the field, you get laboratory performance under the most difficult environments. PI fits many places where 19-inch racks won't go. One man can carry a rugged PI recorder to virtually any test site.

How did PI put precision in a small package? By combining transistorized electronics with unique stacked reel tape magazines. PI recorders use standard tapes and heads, are compatible in every way with standard recording practices and other recording equipment.

KEY SPECIFICATIONS (Model PS-207 Series unit)

FM SYSTEM: Frequency response ±1/2 db 0-10 kc, S/N ratio 43 db, better than 1.5% total harmonic distortion, less than 2% drift 40° to 120° F., linearity 1%.
DIRECT SYSTEM: Response ±3 db 50-100,000 cps.
POWER: 115 vac, 48-62 cps or 24 vdc.
FLUTTER: Less than 0.1% rms dc to 300 cps or .5% peak-to-peak at 30 ips.
PS-207 shown contains electronics for 7 record/reproduce channels.

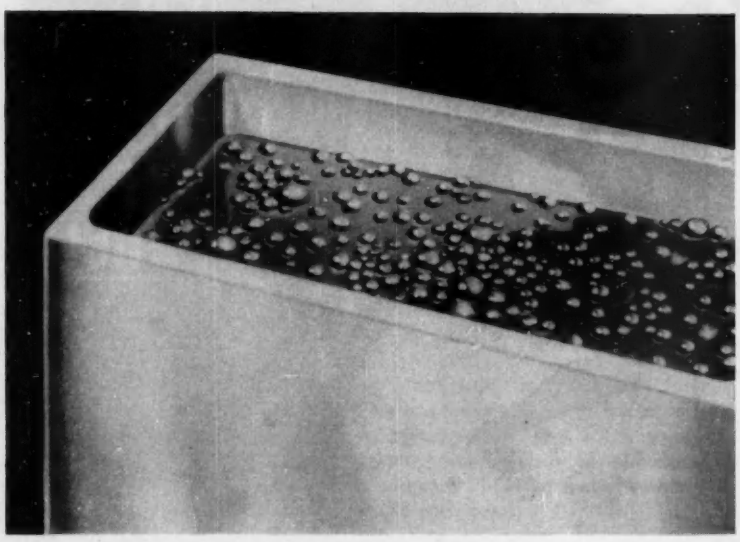
After you note these key specs, may we suggest you call your PI representative to arrange a demonstration? If you are uncertain who he is, please write direct. Address Dept. C 4.

Precision Is Portable

PRECISION INSTRUMENT COMPANY
1011 COMMERCIAL STREET • SAN CARLOS, CALIFORNIA • PHONE: LYTELL 1-4441

CIRCLE 201 ON READER SERVICE CARD 201

ACOUSTICA ULTRASONIC CLEANING REPLACES OLDER METHODS!



Texas Instruments, Martin Company, Bell Telephone Laboratories and many other firms are turning to Acoustica for better cleaning ultrasonically!

Now you can clean better and faster. In seconds—all dirt, dust, and soils are "cavitated" away ultrasonically. No scrubbing, no disassembling, maintenance costs are sharply reduced. Acoustica ultrasonic systems are application tested and *certified* for your particular needs. Send for details of complete Acoustica line of the most advanced ultrasonic equipment and cleaning chemicals. Acoustica Associates, Inc., Fairchild Court, Plainview, N. Y., 10400 Aviation Blvd., Los Angeles, Calif.

CERTIFIED APPLICATIONS

acoustica

ULTRASONIC CLEANING SYSTEMS

202 CIRCLE 202 ON READER SERVICE CARD

what of a disappointment to Manning. Robertshaw President Thomas T. Arden recalls that introduction of the devices was a bit premature; substantial weaning away from pneumatic instruments was needed before wholesale changeovers to electronic instrumentation could have been expected, he says. Manning, with its sales force aligned primarily to sales of its other equipment items, was not really set up to do the applications engineering type of job needed to sell complex electronic gear, according to Arden.

More important, M, M & M lost enthusiam for Microsen after the line's initial lack of success and failed to give the sales push that was needed. Robertshaw has an instrument sales force 10 times the size of Manning's, says Arden, and he intends that Robertshaw salesmen give the Microsen line the necessary promotion. Nothing could be clearer than Arden's confidence in the line. Electronic control, he says, is much more flexible, capable, and a better buy in the long run.

In another recent move Robertshaw bought the Acragage instrument business of International Register Co. of Chicago. Annual sales of the line of commercial indicating pressure gages have been about $400,000 a year. With these additions (Microsen's sales are now at only about $2 million a year), Robertshaw's total instrumentation sales should reach more than $10 million this year.

Sunbeam Corp. Purchases John Oster Mfg.

A stock exchange transaction has resulted in the acquisition of the John Oster Manufacturing Co. by Sunbeam Corp., Chicago maker of portable electrical appliances. Sunbeam expects to continue all the Oster operations as a wholly owned subsidiary, including Oster-owned firms in Mexico and Nassau and other related companies.

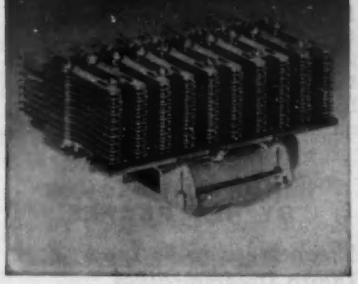
The deal gives Sunbeam a substantial entry into the avionics field with Oster's Avionics Div. sales estimated to exceed $13.5 million this year.

News of Other Companies In the Control Field

The Siegler Corp., Los Angeles, has acquired Magnetic Amplifiers, Inc. of New York. A stock exchange deal merged the producer of solid state equipment, like flight control systems, power supplies, automatic checkout

STROMBERG-CARLSON

"BB" SERIES RELAYS



For your automation ...computing...control circuit applications...

"TELEPHONE QUALITY"

at an ordinary price

To meet your needs for precision and durability in automation, computing and control circuitry, this relay provides *telephone quality* at an ordinary price.

The "BB" Series Relay accommodates up to 100 Form A spring combinations. It incorporates such important advantages as twin contacts, knife-edge pivot and special frame-armature construction. Like all Stromberg-Carlson relays, it is built to operate under extreme ranges of temperature and humidity. *Prompt delivery is available on all orders.*

For full information write to Telecommunication Industrial Sales, 112 Carlson Road, Rochester 3, New York.

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A DIVISION OF
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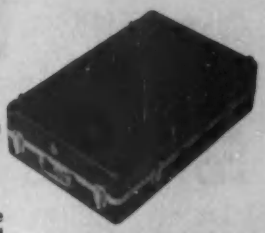
CIRCLE 228 ON READER SERVICE CARD

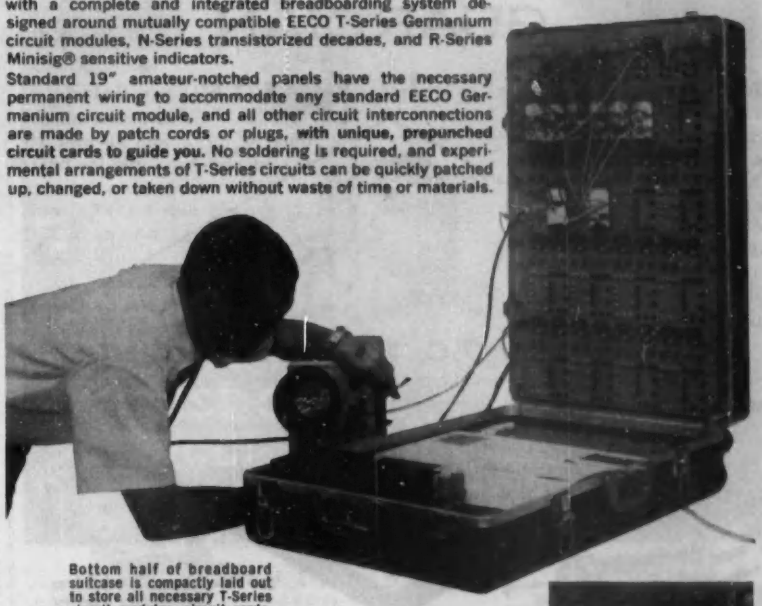
SOMETHING NEW IN A SUITCASE...



...Complete transistorized EECO Digital System Breadboard

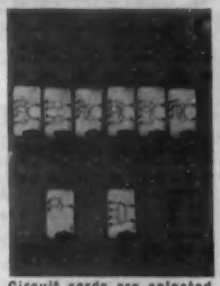
Designers who want to go places fast systemswise can be sure of getting there on time with an EECO suitcase. It's packed with a complete and integrated breadboarding system designed around mutually compatible EECO T-Series Germanium circuit modules, N-Series transistorized decades, and R-Series Minisig® sensitive indicators.

Standard 19" amateur-notched panels have the necessary permanent wiring to accommodate any standard EECO Germanium circuit module, and all other circuit interconnections are made by patch cords or plugs, with unique, prepunched circuit cards to guide you. No soldering is required, and experimental arrangements of T-Series circuits can be quickly patched up, changed, or taken down without waste of time or materials.



Bottom half of breadboard suitcase is compactly laid out to store all necessary T-Series circuit modules, circuit cards, patch cords, and compatible power supplies.

EECO T-Series breadboard equipment is available in both suitcase and rack-mounted types. Breadboard Kits of any degree of complexity can be built up in stages, according to the specific panels and number of circuits incorporated. Compatible interconnections between racks or suitcases further enable the designer to expand the equipment into a complete systems development console. Compatible solid-state, convection-cooled power supplies are also available in two different models: ZA-720 is a dual 12-volt, 5-amp supply; ZA-721 is a 12-volt, 1-amp plug-in power supply.



Circuit cards are selected according to the system it is desired to breadboard and placed on the panel in alignment with the jack pattern. Corresponding T-Series circuit modules are plugged in above each card.

FEATURES

- Permits rapid formulation of digital electrical systems.
- System may be operated slowly to permit inspection of its mode of operation, or over-speed to indicate system derating.
- Operation may be analyzed with a minimum of test equipment.
- Provides a means for rapidly building and testing alternate ways of formulating a system.
- Minimizes wiring errors and the inclusion of defective parts.
- Circuit cards provide a means for rapidly visualizing the system, and facilitate drawing a circuit diagram.
- Circuit cards enable the designer to determine the elements involved, as well as the cost of the system.

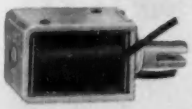
A request, on your company letterhead, will bring detailed information on the flexibility of the EECO T-Series Breadboarding equipment, and a demonstration if desired.

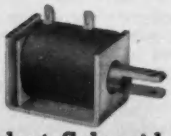
Circuit interconnections are made by patching through holes in the circuit cards. Resulting pattern of symbol cards and patch cords shows a schematic and bill of materials for the system, once it is checked out.

ENGINEERED ELECTRONICS COMPANY
1441 East Chestnut Avenue • Santa Ana, Calif.

CIRCLE 203 ON READER SERVICE CARD

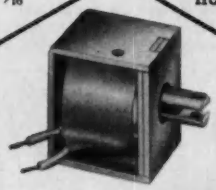
EVERYTHING UNDER CONTROL
with
SOLENOIDS
by
GUARDIAN



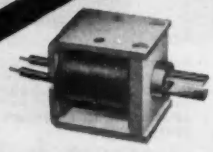


No. 22 D.C. Guardian's "mighty midget". Only ¾" x ¾" x 1⅛" size. Stroke ranges from 1/32" to 5/16" and lifts up to 24 ounces. Available D.C. voltage only for intermittent or continuous duty.

No. 24 A.C. Midget Solenoid. Only 1¼" x 1" x ⅞". Stroke ranges from 1/16" to ⅝" with lift over 19 ounces. Available for intermittent or continuous duty in any A.C. voltage up to 230 V. A.C.



No. 28 A.C. or D.C. MIDGET SOLENOID.
Announcement of this new Guardian midget solenoid will be greeted with eager interest by design engineers. It is most versatile. Has tapered plug and plunger for greater power. Adjustable stroke 1/16" to ½". Lift of over 41 ounces. Only 1⅛" x 1" x 1 3/16". Available A.C. or D.C.; intermittent or continuous duty.

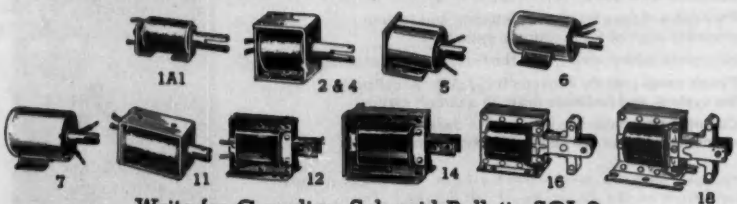


Heavy Duty No. 4 D.C. A version of Guardian's No. 4 solenoid. Has added power lift up to 9 pounds achieved by use of tapered plug and plunger, and special frame. Adjustable stroke ⅛" to ¾". Available for continuous or intermittent duty with D.C. voltages up to 110 V. D.C.

Heavy Duty No. 2 A.C. or D.C. A new version of Guardian's well-known standard No. 2 solenoid having greater power and much longer life expectancy well in excess of 15 million operations. Adjustable stroke ½" to ¾". Lifts more than 95 ounces. Available for A.C. or D.C.; intermittent or continuous duty.

Guardian offers the most complete, flexible and versatile line of solenoids ranging from midgets to heavy duty laminated types and for intermittent or continuous duty. Available with "Permaseal" encapulated coils and in D.C. units for 400 cycle operation.

LARGE SELECTIONS of Guardian Solenoids are carried in stock by Franchised Electronic Parts Distributors in the U. S. and Canada. Write for name of nearby distributor and Bulletin SD-25.



Write for Guardian Solenoid Bulletin SOL-8

GUARDIAN ELECTRIC
MANUFACTURING COMPANY
1558-D W. CARROLL AVENUE, CHICAGO 7, ILLINOIS

WHAT'S NEW

equipment, and other gear, into the diversified corporation.

Bowmar Instrument Corp., Ft. Wayne, Inc., has purchased **Applied Dynamics, Inc.** of Ann Arbor, Mich. A manufacturer for the computer market, ADI will be an independent company under Bomar direction.

American Bosch Arma Corp., Hempstead, N. Y., has bought **Tele-Dynamics, Inc.** of Philadelphia from its parent firm, Raymond Rosen & Co., Inc. As a new division, Tele-Dynamics will continue in the development of telemetry equipment.

IMPORTANT MOVES BY KEY PEOPLE

Skeen Steps In To Lead Temco Diversification

Still another aircraft company set on diversification through electronics (see story on p. 201) is Temco Aircraft Corp. As key figure in the Dallas firm's expansion program, Temco has brought in Clyde Skeen from a job as vice-president for weapons system program management of Boeing Airplane Co.'s Aerospace Div. Skeen will be executive vice-president and general manager, Temco's top operating management post.

Billed "as a major step in the conversion of Temco from an airframe manufacturer and subcontractor into an aerospace corporation with widely diversified capabilities" by President, co-founder, and recently General Manager Robert McCulloch, Temco looks for Skeen to "accelerate advancement in [its] missile, electronic, and aerosystem work."

In addition to its missile and airplane prime contracts, Temco has divisions for overhaul and aerosystems, electronics, and industrial products. It also owns 80 percent of Fenske, Fedrick & Miller, an electronics company specializing in display gear.

In other appointments Temco named Dr. Charles K. Hager as section manager of automatic controls for its Electronics Div. and hired Earl H. Flath, Jr., as a senior scientist in radiation, antennas, and microwave systems.

Bayer New General Manager At W & S's Control Instrument

Lad J. Bayer is now general manager of the Warner & Swasey Co.'s Control

Instrument Div. The division has moved to new manufacturing facilities in Flushing, N. Y., to step up production of its Probomat system of numerical controls.

CID is an outgrowth of Industrial Scientific Co. which was purchased by W & S in 1954. Other products include the Probigraph for measuring odd shapes and hard-to-reach spots.

Locke Heads Brown As Dever Moves to Main Office

Henry F. Dever, vice-president of Minneapolis-Honeywell Regulator Corp. and head of the Industrial Products Group has transferred from Philadelphia to company headquarters in Minneapolis. Move was dictated by need for chiefs of product groups to be based at the home plant.

As new general manager of Brown Instruments Div., Honeywell named James S. Locke, a newly elected corporate vice-president. Locke will also be responsible for the Valve Div. (Fort Washington, Pa.) and the Fall River, Mass., Div.

Dr. Walsh at CEIR As Space Director

Dr. J. Paul Walsh, former deputy director of Project Vanguard and systems manager for special projects at IBM's Federal Systems Div., has joined CEIR, Inc. as director of its Space and Weapons Systems Div.

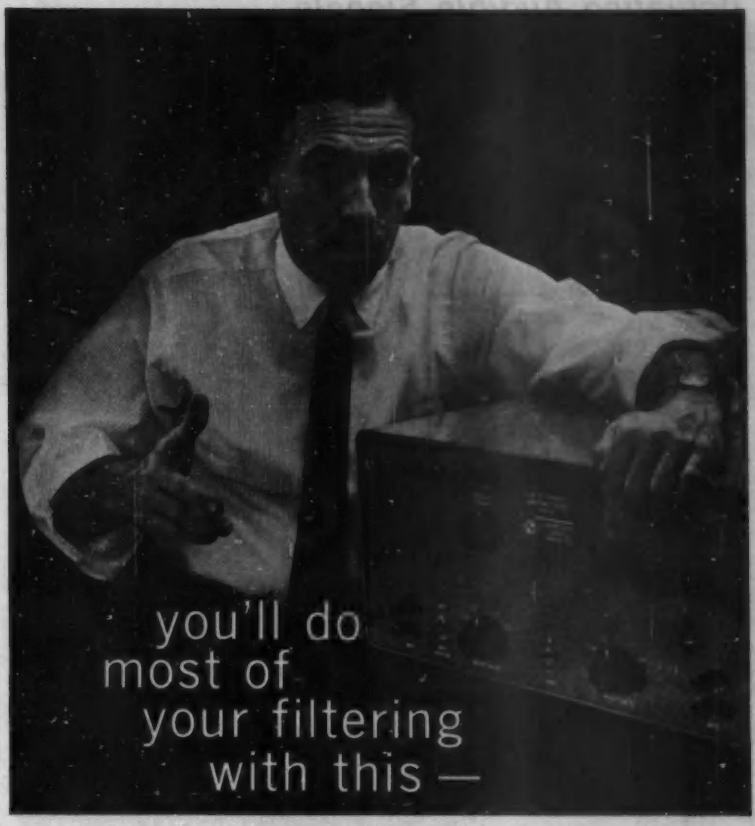
During his 15 years with the U. S. Naval Research Laboratory, Dr. Walsh participated in Operation Crossroads, the first atomic bomb test at Bikini and did planning, research, and engineering work on reactor compartments for nuclear submarines. In his new position with CEIR (Arlington, Va.) he will direct expanding work of the research and computer services firm in space technology and related fields.

Other Important Moves

David William Moore is now manager of the Solid State Physics Lab of Lear, Inc., Los Angeles. He's been with Servomechanisms, Inc. for the past 10 years.

Stephen M. Fillebrown has become manager of digital equipment engineering for Rese Engineering, Inc. of Philadelphia, manufacturers of high speed digital memories and digital plug-in circuits.

John F. Price is new engineering manager for the West Coast Div. of the Military Electronic Operations of Allen B. Du Mont Laboratories, Inc.



because only the 330-M is continuously variable from 0.2 cps to 20 kc!

Now you can cover the complete frequency range from sub-audio through audio with one convenient variable electronic filter! Its bandwidth covers the most widely used frequencies in circuitry design, testing, measurement and research. The 330-M can replace — in a 17" x 8" x 12" size — banks of fixed filters, and massive inductors and capacitors.

More than this most frequently used bandwidth, the 330-M band-pass filter offers rapid attenuation beyond the cut-offs. Unwanted signals are attenuated up to 80 db, and maximum attenuation is *maintained* at all frequencies beyond cut-off. Low cut-off, high cut-off and center frequency are all continuously variable. Cut-off frequency dials are single log-scale, direct reading. Band switches give frequency ranges in five decades. Attenuation is 24 db per octave outside the pass-band, reaching 70 db in less than three octaves. Signal-to-noise ratio is greater than 80 db.

Write for full information on this wide-band, light-weight band-pass filter. Its convenient coverage of low frequencies through audio, and direct reading, continuously variable cut-offs give you real work-load flexibility. Other Krohn-Hite band-pass filters include Models 330-A (0.02 to 2,000 cps), 310-AB (20 to 200,000 cps); and rejection filters as well. *Also, Krohn-Hite Oscillators, Amplifiers and Power Supplies.*

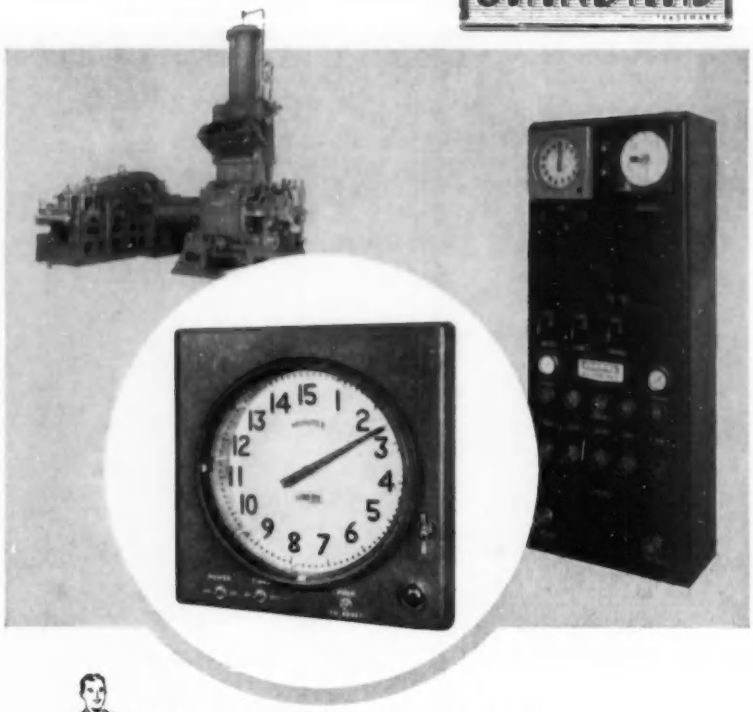
KROHN-HITE CORPORATION
580 Massachusetts Avenue • Cambridge 39, Mass.
Pioneering in Quality Electronic Instruments

CIRCLE 205 ON READER SERVICE CARD 205

Actuating Audible Signals . . .

Another of Countless Applications of

SPECIAL TIMERS by STANDARD



A specially developed Standard batch timer, with pins which can be positioned as desired, actuates audible signals to assure proper manual operation of critical equipment.

What's *your* need in special timers? Precise process timing—as on this Farrel-Birmingham Banbury® mixer? Or accurate test timing (to tolerances of ± .001 second)—as with numerous electronics and missile manufacturers?

Whatever the application, STANDARD stands ready to develop the exact elapsed time indicator to meet the most stringent requirements.

Inquire today.

Request Catalog No. 198A covering the full line of STANDARD Precision Timers . . . portable or panel mounted.

"Splitting the Split Second . . . Precisely"

THE STANDARD ELECTRIC TIME COMPANY

89 LOGAN STREET, SPRINGFIELD, MASSACHUSETTS

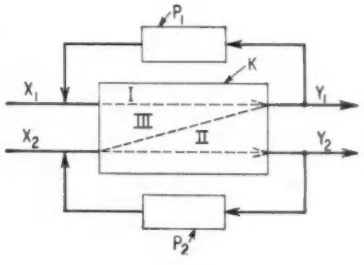
ABSTRACTS

Column Controller

From "Automatic Control of a Distillation Column for Concentrating Nitric Acid" by V. N. Kragnov. Instrument Construction, pp. 1-5, April 1959. Translated from Russian, printed, and published by Taylor & Francis Ltd., London, for the British Scientific Instrument Research Assn.

In the distillation column nitric acid is evaporated out of a mixture of nitric acid, sulphuric acid, and water. Composition of concentrated nitric acid is maintained by controlling the temperature of the column's upper section by regulating the flow of steam into the column. Composition of the used sulphuric acid is maintained by controlling the temperature of the fourth (from the bottom) section by regulating the sulphuric acid intake.

Analysis of the basic process and the influence of disturbances resulted in the block diagram (figure) indicating three control channels or transfer functions: X_1/Y_1, X_2/Y_2, and X_2/Y_1. Here, P_1 controls the drying zone temperature, P_2 controls the temperature of the lower part of the column, X_1 is the steam intake, X_2 is the sulphuric acid intake, and Y_1 and Y_2 are the controlled temperatures.



Step change disturbances were introduced to obtain the response characteristics for the three transfer functions. Mathematical treatment of the responses showed that the process could be adequately characterized by one second order and two third order differential equations. Tests and analysis also indicated that large disturbances caused unstable oscillations without controllers. Cause of the oscillations lies in the presence of tray-to-tray feedback which increases with large disturbances.

To determine needed controller characteristics for a stable process, frequency response plots were made from the differential equations and

later confirmed by sinusoidal tests on the process itself. Optimum controller settings were then calculated from these plots.

Analysis of transient responses of the controlled system with both two- and three-term controllers showed that: 1) for temperature control of the drying zone, a two-term controller with a damping factor of 0.75 would be adequate and simpler to operate and maintain than a three-term controller, and 2) for temperature control of the column bottom, a two-term controller with a damping factor of 0.9 would be adequate.

"By going from manual to automatic control the quality of products has been considerably improved. Variations in the concentration of strong nitric acid have fallen from 2 percent to 0.1-0.2 percent with minimum amounts of oxides of nitrogen. Variations in the concentration of used sulphuric acid have fallen from 2.5-3.0 percent to a few tenths of a percent with a normal proportion of nitric acid in sulphuric acid. . .

"Savings . . . are expected to reach several hundred thousand rubles annually, and the capital expenditure on installing the automatic control system should be paid off in one year."

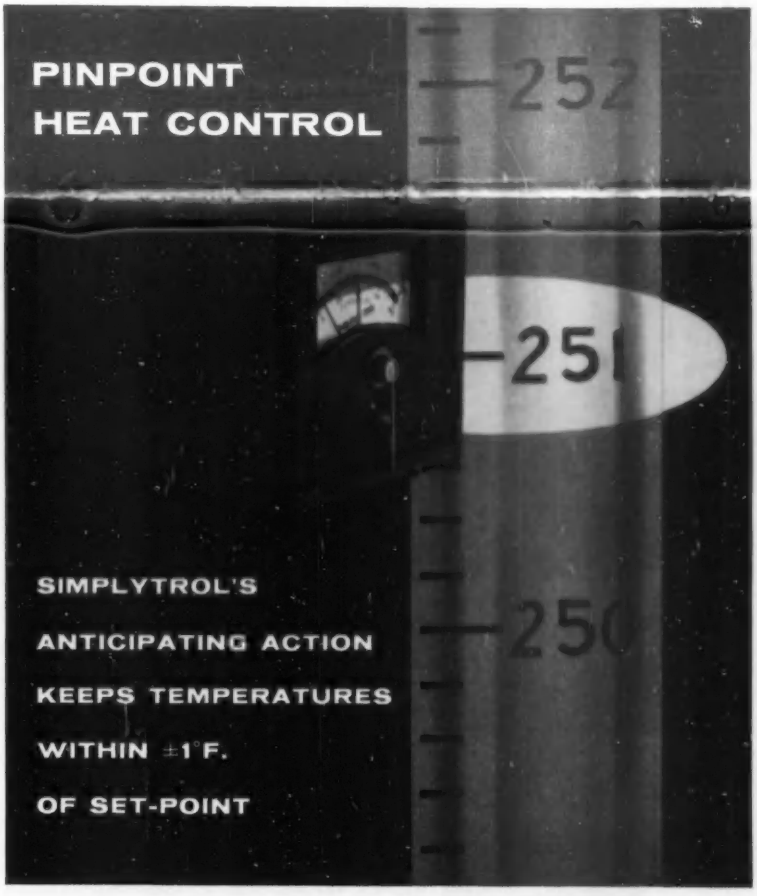
Promising Switch

From "The Ferreed—A New Switching Device" by A. Feiner, C. A. Lovell, T. N. Lowry, and P. G. Ridinger. The Bell System Technical Journal, pp. 1-30, January 1960.

An experimental switching device is described having the following properties: sealed metallic contacts, control times in the microsec range, coincident selection, memory without holding power, and small size. These properties make the device attractive for use as network crosspoints in electronic switching systems.

The ferreed, as its name implies, comprises a magnetically hard ferrite member in combination with a magnetic reed switch. The switch consists of two soft magnetic reeds, which are responsive to the remnant magnetic field of the ferrite, and which also serve as electrical contacts.

A pair of overlapping reeds is fastened between the ends of a semicircular ferrite member. An exciting winding is uniformly distributed over the length of the ferrite. A short pulse of current applied to the exciting winding magnetizes the ferrite, which in turn induces unlike magnetic poles at the overlapping ends of the reeds. The reeds are mutually attracted, and, if the remaining flux is sufficient to overcome the spring force, the reeds



Temperature controlled by the Simplytrol behaves the way you want it to. It doesn't soar or sag. It can't. Simplytrol's special time-proportioning anticipating circuit senses temperature build-ups, and modifies the heat cycle well before over-shoots can occur. Control consistently follows the straight-and-narrow . . . within ±1°F. of set-point.

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There are three basic Simplytrol models available in thirty ranges from −400°F. to 3000°F., and packaged in a variety of mounting cases. One could be just the temperature controller you've been looking for. All are fully described in new Bulletin 108 . . . yours for the asking.

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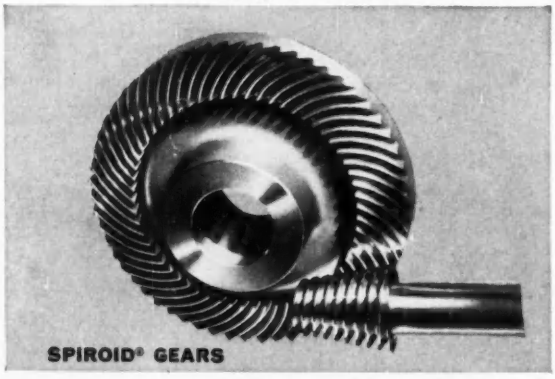

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ABSTRACTS

will close, thereby establishing an electrical connection.

The connection is released by an exciting current pulse smaller in magnitude and of opposite polarity, which reduces the remnant flux of the ferrite member below that value necessary to hold the reeds closed.

Because the device incorporates internal magnetic memory, it can be interrogated without its electrical output circuit being disturbed. Methods of nondestructive readout of the memory may be adapted from magnetic core technology.

Better ferroelectrics

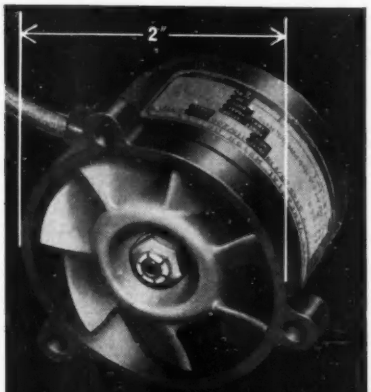
From "Research on Barium Titanate and Other Ferroelectric Materials for Use as Information Storage Media", by Charles F. Pulvari, Catholic University of America for Wright Air Development Center, U.S. Air Force, Sept. 1958. Now available from Office of Technical Services, U.S. Dept. of Commerce, Washington 25, D.C., as PB 151835, 238 pp., $3.50.

Earlier research headed by Prof. Pulvari on ferroelectric barium titanate and its usefulness as a storage medium produced proof of the feasibility of ferroelectric materials for digital and tape storage devices. This final report presents practical and theoretical work leading to refined $BaTiO_3$, tri-glycine sulfate, and tri-glycine fluoberyllate materials and to improved methods of producing industrially useful storage condensers. It also describes the actual devices, developed and operating, for information storage and other purposes, which bear out the practicability of ferroelectric devices. (The initial report on the research was previously released through OTS and is still available. It is PB 121384 *Determining the Usefulness of Barium Titanate Materials for Memory Devices in Large-Scale Digital Calculators*, April 1956, 86 pages, $2.25.)

Experience on pipelines

From "Requirements For Electric Control Valve Operators For Pipe Line Service" by R. J. Osborn, Sinclair Pipe Line Co. Preprint number 19H60, presented at the ISA Winter Instrument-Automation Conference and Exhibit, Houston, Texas, Feb. 1-4, 1960.

The control valve is the primary method of pipe line control at the



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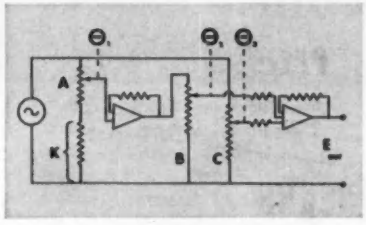
DESIGN IDEAS FOR ELECTRONIC ENGINEERS:

How to design better analog computing circuits with Vernistat* a. c. potentiometers

Analog computers typically use such components as potentiometers, resolvers, and linear synchros to relate shaft position to voltage. In most applications, to reduce the effect of loading error, high impedance circuits, and phase shift, a substantial amount of additional equipment, such as isolation amplifiers and auxiliary power supplies, is required. Size, weight, heat dissipation, and possibility of failure are thus greater than if loading error, phase shift, and high output impedance problems did not exist.

Typical of a class of equations which are incorporated into much analog computer circuitry is the relation

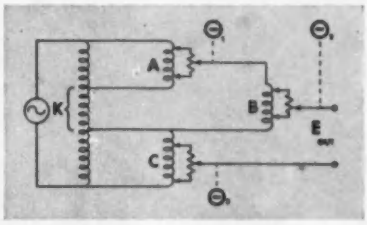
$$E_{out} = [K + A(\Theta_1)]\, B(\Theta_2) + C(\Theta_3).$$



ONE WAY TO SOLVE this relation is shown in this diagram of a conventional resistance potentiometer computing circuit. Such circuits, however, suffer from excessive phase shift, particularly at high frequencies.

Due to high potentiometer output impedances, the circuit requires an isolation amplifier in the multiplying channel, while summing resistors and a feedback amplifier are required in the addition section. Both of these amplifiers, as additional components, add a factor of unreliability and use more power, increasing the problem of heat dissipation.

A MORE EFFICIENT WAY TO SOLVE this equation is with Vernistat a.c. Potentiometers. The Vernistat is an ideal component for analog computer systems. Its combination of a tapped autotransformer and an interpolating potentiometer uniquely provide characteristics unobtainable with other types of shaft position-voltage devices. The Vernistat provides precise voltage division, high input impedance, low output impedance, and low phase shift. These characteristics directly relate to the design of improved computer circuits.



FOR EXAMPLE, in the computer circuit shown here, multiplication may be performed without the aid of an isolation amplifier, because of the Vernistat's high ratio of input to output impedance. Addition is accomplished by utilizing voltages of opposite phase in the two computing channels obtained by a tapped input transformer. By eliminating the amplifiers of the preceding circuit, a reduction of size, weight, heat rise, and power requirements is obtained. With fewer components required, there is an over-all increase in reliability.

IN SOLVING DESIGN PROBLEMS like these, Vernistat a.c. Potentiometers offer such major advantages as: low output impedance (as low as 40 ohms) with high input impedance (as high as 200,000 ohms)—high resolution (to 0.002%)—low phase shift (as low as 0.2 minutes)—and high terminal linearity (to 0.01%). Vernistats meet the requirements of MIL E 005272-B, and operate at 125°C without derating.

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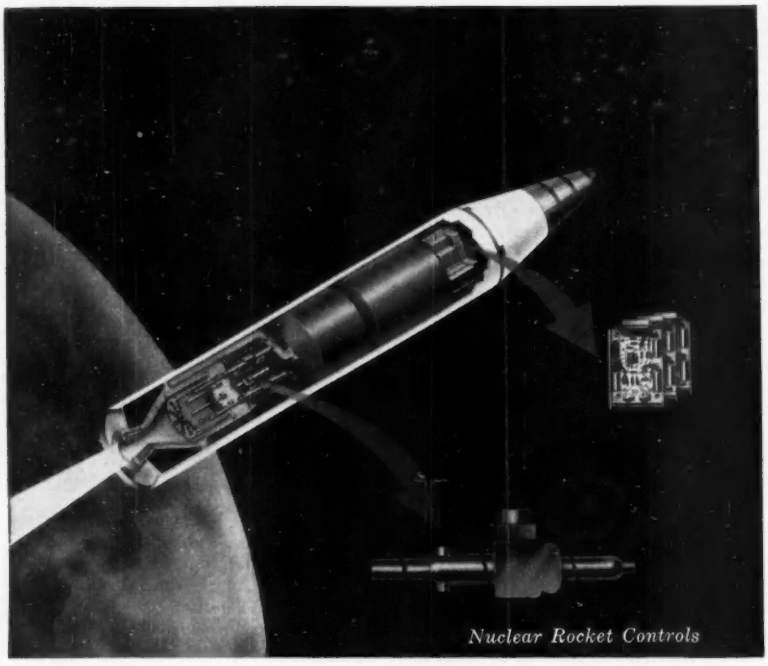
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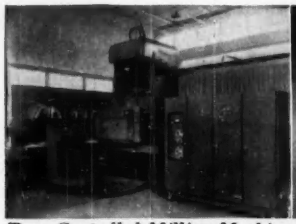
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present time even though power losses associated with control valves become quite large in high capacity liquid pipe lines. The need for electric control valves arises because most pumping stations, using a single control valve, are remote and unattended. Thus, it is impractical to use pneumatic control valves with their associated costly air compressors, filters, and dryers, whose maintenance is handled by crews stationed 100 or more miles away.

The pipeline control valve is most often called on to:

Limit line pressure to a safe value.

Limit minimum pump suction pressure to avoid pump cavitation.

Limit the load on the prime mover.

Limit the overall power demand for the station.

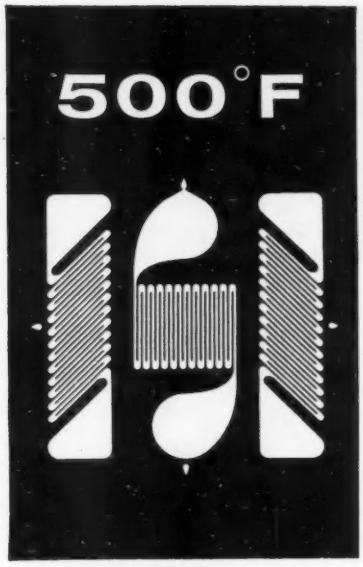
The valve is not used to maintain these variables at a specific value, but rather to keep them from exceeding a safe limit in on direction only. The paper discussed how these variables may reach unsafe conditions during pipeline operation.

A second section of the paper tabulates actual operating experience with several makes of electrical control valve operators, although it does not identify the makers by name. On the basis of users' comments, it would appear that currently available electric operators are performing well and have sufficient stroke speed to meet many needs. However, most pipeline companies will be interested in faster operators to minimize line upsets.

Backlashless universal

From "'No Backlash' Universal Joint", by R. E. Stokely, Borg-Warner Corp. for Wright Air Development Center, U.S. Air Force, March 1959. Now available from Office of Technical Services, U.S. Dept. of Commerce, Washington 25, D.C., as PB 161031, 23 pp., $0.75.

Development of unique preloaded tapered roller bearings led to construction of a universal joint with no backlash. Preloading eliminates any play between the bearing and the trunnion when a torque load applied on the joint is fully reversed from plus 8 in.-lbs. clockwise to minus 8 in.-lbs counterclockwise. The "no backlash" joint is interchangeable with universal joints meeting requirements of MIL-U-3963. The report contains photos, design drawings, and descriptions of test specifications.



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NEW BOOKS

Updated Text

PRINCIPLES OF DIRECT-CURRENT MACHINES. *Alexander S. Langsdorf. 363 pp. Published by McGraw-Hill Book Co., Inc., New York. $8.50.*

This text presents a compact analysis of the operating characteristics of generators and motors. The basic principles of electromagnetism needed in developing the characteristics of rotating machines are developed in the opening chapter, which includes also a discussion of the systems of units in which magnetic and electrical quantities are expressed. The remainder of the book is concerned with the properties and construction of the machines themselves. Design considerations which determine the physical dimensions of machines are touched upon only briefly.

In this sixth edition the first five chapters of the previous edition have been eliminated, except for the parts dealing with electromagnetism. The chapter on "Armature Windings" is completely rewritten and simplified and now includes a description of a new type of unipolar generator. In addition, it contains the development of the emf formula for dc machines, which is a departure from the usual practice of delaying this derivation until later. The new method used in this derivation leads in turn to the analysis of the emf pulsations by a new procedure.

Since the time now devoted to courses in dc machinery in electrical engineering curricula is, in general, limited, the length of this text has been correspondingly reduced. All line drawings and halftone illustrations are new as is the problem material at the end of the book.

Guide to Service

INDUSTRIAL INSTRUMENT SERVICING HANDBOOK. *Grady C. Carroll, 848 pp. Published by McGraw-Hill Book Co., Inc., New York. $16.*

This handbook has been prepared to supply information needed regularly in the field or shop for the servicing and maintenance of modern industrial process measuring and control instruments. The editor has attempted to cover this broad subject in such a manner that it will be useful as a reference for the practical man and as a text for apprentices receiving their training through trade schools, vocational schools, industrial

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plant training programs, and technical institutes. It is also believed useful for chemical engineering students in their senior year.

The handbook covers a cross section of the industrial instruments manufactured by 41 companies. In addition to this, it furnishes information on organizing an instrument maintenance department and selecting personnel for it. Along with organizational charts and scheduling systems for preventive maintenance, trouble-shooting charts are provided to assist in locating faulty components without a complete analysis of pneumatic and electrical circuits. Photographs and circuit diagrams are included.

The material is presented in step-by-step fashion. First, the principle of operation of the instrument is explained; then, the proper methods to be used in servicing, maintaining, and trouble shooting are explained; and finally, complete calibration instructions are given.

Research Roster

FEDERAL AGENCIES FINANCING RESEARCH. *Document 14 published by Social Legislation Information Service, 1346 Connecticut Ave., N.W., Washington 6, D.C.* $1.

This Document is designed to guide the investigator directly to the Federal bureau or agency that may best utilize his special competences. The detailed index lists scientific fields and indicates the agencies sponsoring extramural research in each field. The Federal offices are then listed alphabetically under the heading of their parent department or agency. The programs, procedures, and organization of each are summarized to indicate generally the design of each research program.

For the Layman

COMPUTERS AND HOW THEY WORK. *James D. Fahnestock. 169 pp. Published by Ziff-Davis Publishing Co., New York.* $4.95.

This is a comprehensive study of electronic computers that describes in fundamental terms basic computer operating principles, programming, manufacture, and maintenance. The language is free from highly technical terminology in conformance with the author's stated intention to make the book understandable to as many non-computer-trained persons as possible, even his wife.

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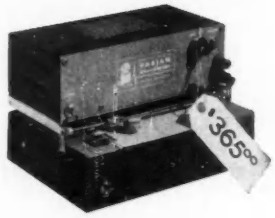

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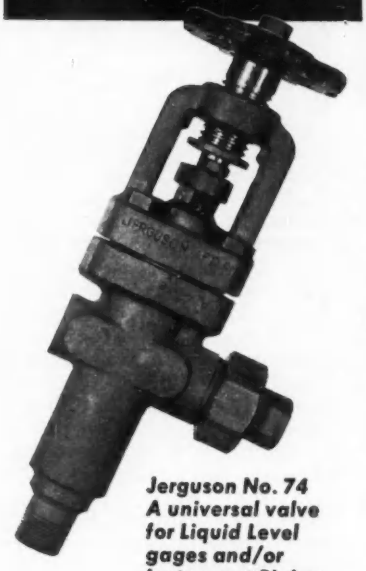

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MEETINGS

APRIL

Sixth Nuclear Congress, sponsored by ISA and Engineers Joint Council, New York City April 3-8

Instrument Society of America, Symposium on Computers in the Process Industry, sponsored by N. J. Section, Hotel Essex House, Newark, N. J. April 5

Third National Chemical and Petroleum Instrumentation Symposium, Rochester, N. Y. April 5-7

American Institute of Electrical Engineers, First Special Conference on Electrical Engineering in Space Technology, Baker Hotel, Dallas, Tex. April 11-13

Conference on Automatic Techniques, sponsored by IRE, AIEE, ASME, Sheraton Cleveland Hotel, Cleveland, Ohio April 18-19

Institute of Radio Engineers, Southwest Regional Conference and Electronics Show, Shamrock-Hilton Hotel, Houston, Tex. April 20-22

Texas A&M Symposium on Instrumentation, Campus, Bryan, Tex. April 20-22

American Society of Mechanical Engineers, Society for the Advancement of Management, Management Conference, Statler-Hilton Hotel, New York April 21-22

American Society of Tool Engineers, 1960 Tool Show, Detroit, Mich. April 21-28

MAY

Institute of Radio Engineers, 12th Annual National Aeronautical Electronics Conference, Dayton, Ohio May 2-4

Instrument Society of America, Sixth National Flight Test Instrumentation Symposium, Hotel Del Coronado, San Diego, Calif. May 2-5

Western Joint Computer Conference, sponsored by IRE, AIEE, ACM, Jack Tar Hotel, San Francisco, Calif. May 3-5

National Association of Relay Manufacturers, Eighth Annual Conference, Oklahoma State University, Stillwater, Okla. May 3-5

Instrument Society of America, Third National Power Instrumentation Symposium, San Francisco State College, San Francisco, Calif. May 9-11

American Society for Metals, Second Southwestern Metal Congress and Exposition, Sheraton Dallas Hotel, Dallas, Tex. May 9-13

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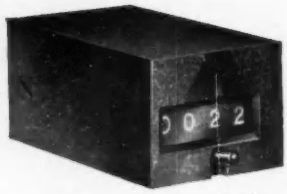

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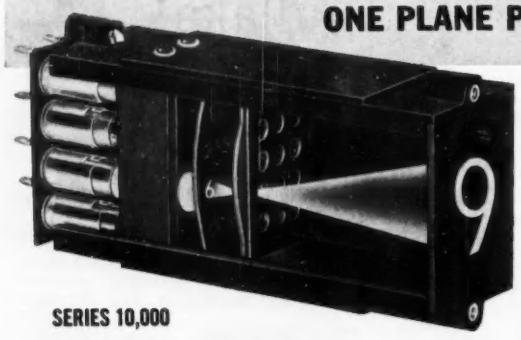

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Electronic Components Symposium, sponsored by IRE, AIEE, EIA, WEMA, Washington, D. C. May 10-12

American Material Handling Society, Third Western Regional Material Handling Show and Packaging Cavalcade, Great Western Exhibit Center, Los Angeles, Calif. May 11-13

Superconductive Techniques for Computing Systems Symposium, sponsored by Office of Naval Research (Information Systems Branch), Department of Interior Auditorium, Washington, D. C. May 17-18

American Society of Mechanical Engineers, Production Engineering Conference, Hotel Schroeder, Milwaukee, Wis. May 17-19

American Society of Mechanical Engineers, Oil and Gas Power Conference and Exhibit, Muehlebach Hotel, Kansas City, Mo. May 22-26

Ninth National Telemetering Conference, Miramar Hotel, Santa Barbara, Calif. May 23-25

American Society of Mechanical Engineers, Design Engineering Conference and Show, Statler-Hilton Hotel, New York. May 23-26

International Instruments, Electronics, and Automation Exhibition, Olympia, London, England May 23-28

Conference on Automatic Computing and Data Processing in Australia, University of Sydney, University of New South Wales May 24-27

JUNE

Instrument Society of America, Sixth Annual Instrumental Methods of Analysis Symposium, Montreal, Canada June 1-3

American Society of Mechanical Engineers, Semiannual Meeting, Statler-Hilton Hotel, Dallas, Tex. June 5-9

Material Handling Institute, New England Show, Commonwealth Armory, Boston, Mass. June 6-8

American Institute of Electrical Engineers, Summer General Meeting, Atlantic City, N. J. June 20-24

Institute of Radio Engineers, Fourth National Convention on Military Electronics, Sheraton-Park Hotel, Washington, D. C. June 27-29

International Federation of Automatic Control, First International Congress on Automatic Control, Moscow, U.S.S.R. June 27-July 6

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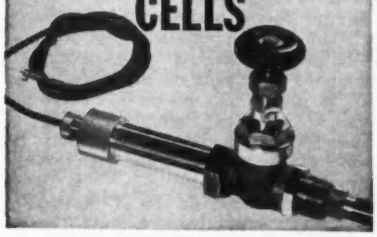

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Ready Reference Data Files—I, II, III, 76 pp. The feature here is a special rate for those who purchase all of the Data Files published in CONTROL ENGINEERING through April 1960. The 36 articles included in this package cover analysis, design, and application short-cuts for all phases of the control field. Everyone can use this timeless reference material. $1.35.

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Ready Reference Data Files—II, 24 pp. Includes the second dozen data files published in Control Engineering. Add Data Files—I to keep your personal file up to date. Topics covered range from analyzing hydraulic servos graphically to using silicon diodes as protective devices. 50 cents.

Continued on page 216

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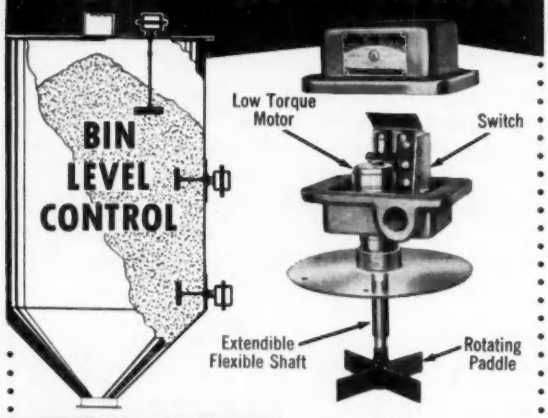

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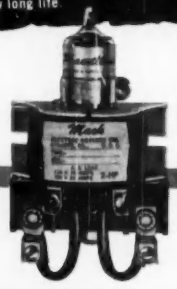

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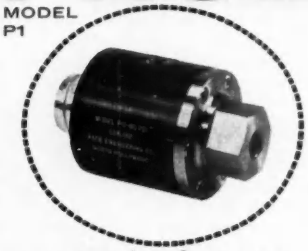

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How to Specify Instrument Accuracy, 8 pp. This basic reprint is aimed at helping the user and maker to develop clear and mutual agreement on allowable instrument errors. Discussions of uncertainties of zero, scale factor, and instantaneous slope aid in the intelligent specification of allowable errors and preferred test procedures. 40 cents.

Transparent Template for Designing Servo Compensators, November 1959, 3 pp. plus template. Includes transparent decibel vs phase angle template on clear acetate in addition to three-page Data File outlining development of template and showing its use through sample problem. 75 cents.

How to Use the Root Locus in Control System Design, 12 pp. Another reprint that translates theory into practice. Eight simple rules make locus construction easy, even including the effects of distance-velocity lags. Articles show how to interpret the locus diagram, how to determine transient response, and how to use locus techniques with multiloop systems. 45 cents.

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Analysis Instrumentation — I — Nuclear Magnetic Resonance, Chromatography, Radioactivity, 32 pp. Reprint consists of first 4 articles of Analysis Instrumentation Series: a general introduction and detailed discussions of the three analysis techniques. Emphasis is on basic principles, practical tips, and the use of these techniques in automatic process control. 60 cents.

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Survey of Ac Adjustable-Speed Drive Systems, June 1959, 16 pp. Largely regarded as constant-speed devices, multi-speed ac actuators actually take many efficient forms. The recent resurgence of interest in these ac adjustable-speed systems prompted this comprehensive coverage of pole-changing techniques, armature resistance control of wound-rotor motors, frequency changing, slip-frequency injection, and the use of eddy-current couplings. 50 cents.

A New Way to Select the Best Control Valve, 16 pp. This three-article reprint takes a fresh look at the problem of specifying process flow control valves. The author gives rules for selecting the right valve characteristics based on static and dynamic considerations, takes into account the influence of piping on valve performance, and tackles the problem of sizing valves for maximum flow and for control rangeability. 50 cents.

Fundamentals of Tie-Motor Control, 12 pp. Although high-powered synchro-tie systems have been around for a long time, only recently has enough experience been logged to put their design on a scientific, rather than cut-and-try, basis. This reprint examines the types of motors that can be used in the light of the application characteristics, and considers the special circuit designs that are required. 30 cents.

Applying Phase-Plane Techniques to Nonlinear System Design, 16 pp. This series of three articles is designed to teach the use of phase-plane techniques to working system designers, on a practical rather than theoretical basis. It tells how to construct a phase-plane plot, how to interpret a plot in terms of system performance, and how to synthesize nonlinear systems using phase-plane techniques. 50 cents.

Economics in Control, December 1958, 24 pp. A special report covering the economic aspects of modernizing with control systems. It starts off with a guide to the financial factors of modernization, then tells the control engineer how to spot opportunities where the addition of instrumentation and control equipment will earn money, and concludes with nine case histories showing specific benefits of modernizing with control systems. 50 cents.

Static Switching Devices—New Tools for Industrial Control, May 1957, 28 pp. An independent consultant analyzes the complete field of industrial static-switching systems. Starting off with a review of basic switching logic, he covers circuit characteristics of the fundamental devices. commercially-available systems, actual applications, etc. 50 cents.

How to Calculate a Control Earning Index, 12 pp. Shows a four-step method for predicting the increment of improved plant economy resulting from the addition of instruments and controls, and reports on experience in applying this method to three typical industrial processes. 30 cents.

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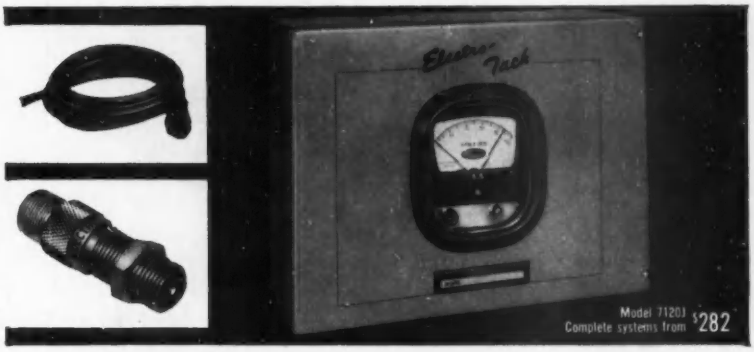

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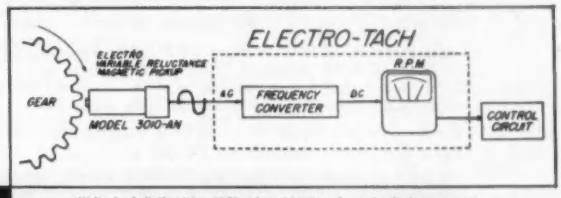

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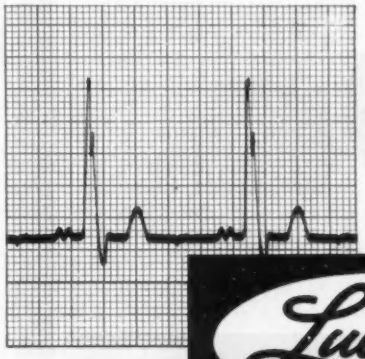

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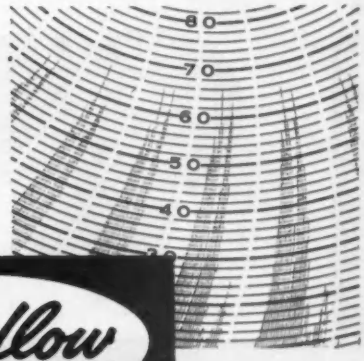

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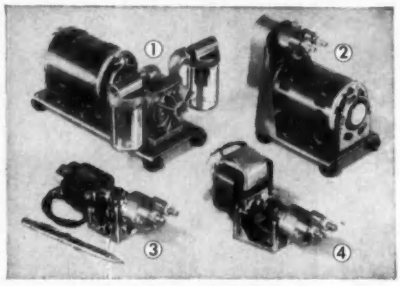

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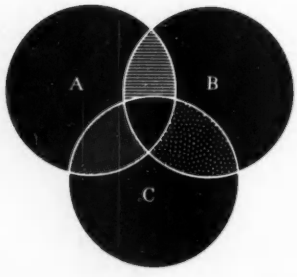

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What's Available in Flowmeters, 24 pp. A comprehensive coverage of positive displacement, velocity, and mass flowmeters, including characteristics, applications, and typical manufacturers; plus details of a special drag disc meter. 50 cents.

The Use of Digital Computers in Science in Business, and in Control, 112 pp. 14 articles published over two years as the Digital Application Series. Covers application, programming, over-all system design, and commercial availability of digital computers. $3.

Selecting and Applying Control Timers, 24 pp. A compilation of four articles including a tabular description of timer functional parts, criteria for selecting and applying control timers, a tabular listing of available timer types and their characteristics, and techniques for custom-designing controls for time-based routines. 50 cents.

What the Control Engineer Should Know About Reliability, April 1958, 8 pp. Not intended as a comprehensive treatise, but rather as a guide to aim the control engineer in the right direction, this staff-written article discusses the new concept of systems effectiveness, and briefly covers techniques for measuring reliability, predicting reliability, improving reliability, and costing reliability. Up to date reference sources increase the value. 20 cents.

Servo Modulators—Their Application, Characteristics, and Availability, 36 pp. A group of four integrated articles covering all phases of electromechanical, electronic, solid-state, and magnetic modulators. Typical circuit diagrams, characteristics, and applications are given for each type, plus an 84-item bibliography and tables listing commercial units. 65 cents.

Basic Data on Process Control, 24 pp. A grouping of five articles on flow-process control, including Basic Concepts of Feedback Control, Selecting Loops for Critical Control, Direct or Reverse Controller Actions, Modifying Valve Characteristics to Fit the Process, and Using Capacitance for Accurate Level Measurement. 50 cents.

How to Simulate Dead Time, 6 pp. Three tricky techniques for simulating dead time or transport lag. One's electronic, another is pneumatic mechanical, and the third uses magnetic tape. A useful reference for control engineers concerned with process simulation. 15 cents.

Transistor and Thyratron Power Amplifiers, 28 pp. These three articles—one on transistors and two on thyratrons—were prompted by the increasing control application of transistors at low-power amplifiers and thyratrons as high-power amplifiers. In each case the emphasis is on practical application, circuit design, system stabilization, etc. 50 cents.

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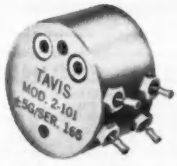

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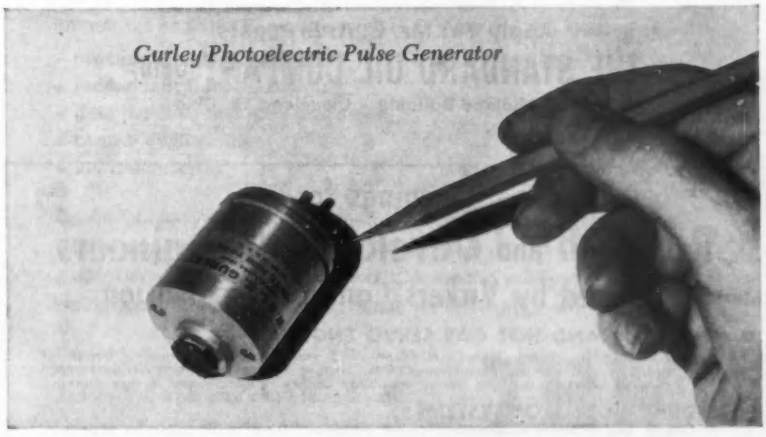

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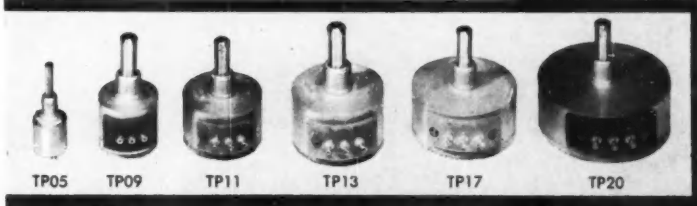

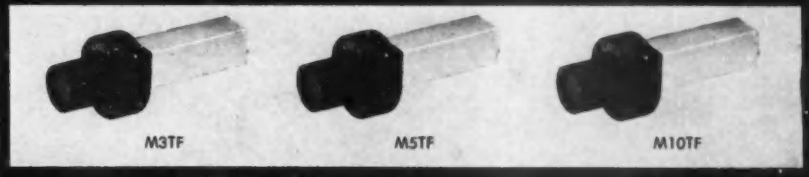

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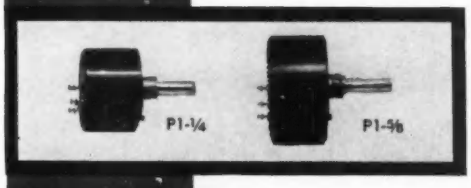

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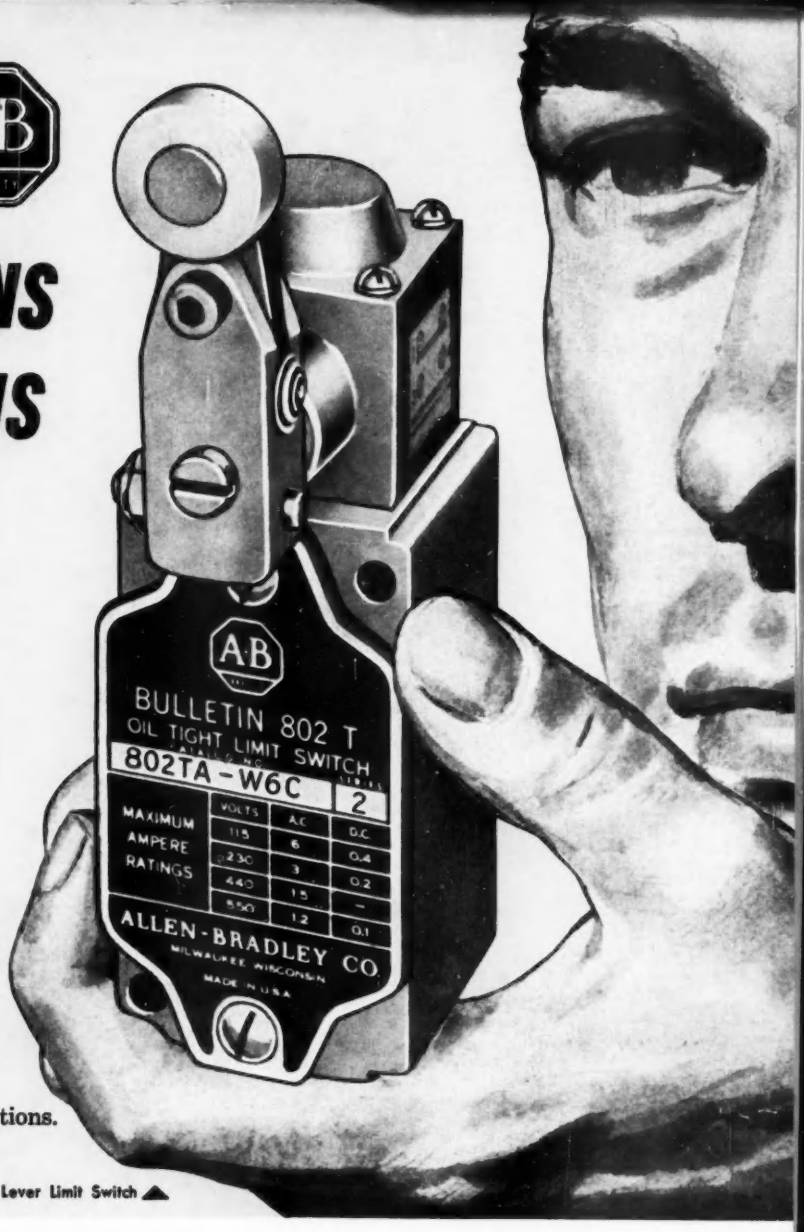

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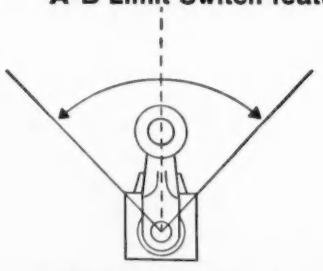

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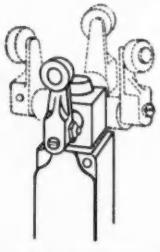

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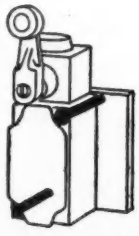

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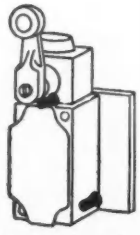

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